ECONOMIC GEOLOGY

WITH WHICH IS INCORPORATED

THE AMERICAN GEOLOGIST

VOL. VIII DECEMBER, 1913 No. 8

THE PLANE-TABLE IN GEOLOGIC MAPPING WITH ESPECIAL REFERENCE TO GRAPHIC HORIZONTAL CONTROL BY INTERSECTION METHODS.

D. F. HIGGINS.

PAGE

Introduction 730
Purpose and Scope 730
Geologist's Three Elements of Position 731
Determination by Distance and Angle Methods (Traverse) 732
Distance Measurements 732
Angle Measurements 732
Determination by Intersection Methods 733
Base Lines 733
The Graphic Control Net 735
Reconnaissance 735
Topography 736
Intervisibility of stations 736
Angles 736
Rules of Graphic Control 739
Methods of Base Expansion and of Carrying Forward Graphic Control 740
Quadrilateral Method 740
Polygon Method 741
Triangle Method 741
Exterior Triangle Method 742
Auxiliary Point Method 742
Broken Base Method 742
Half Quadrilateral Method 744
Details of Procedure—the Quadrilateral Method 744

Vertical Position 748
Determination by Various Methods 748
Topographic Sketching 749
Geologic Position 749
Observations on Lithology, Structure, etc. 749
Delineation of Geologic Data 750
Costs 750
Summary 751

INTRODUCTION.

The utility of the plane-table in geologic mapping is not as much a matter requiring demonstration as it was a decade ago. The plane-table is a rapid and accurate instrument when it is in the hands of one acquainted with its possibilities, and hence its increasing use is a sign of healthy growth in geologic work. For accuracy, speed, and satisfaction the plane-table cannot be equalled by any other instrument in geologic mapping.[1] In the articles which have appeared in ECONOMIC GEOLOGY on the subject of the plane-table in geologic mapping the particulars of equipment for the mapping geologist have been very fully and satisfactorily discussed. It seems, however, that more might be said on the subject of the manipulation of the plane-table, especially in connection with the graphic control of horizontal position. A review of the general principles underlying the particular cases may lead to a better understanding of their application. The matter here has been gathered from theory and from the experience of professional mappists, and it is hoped that it will be of service to those interested in the use of the plane-table.

Purpose and Scope.—The present paper does not undertake to cover all of the uses of the plane-table but it purposes to treat briefly of certain facts and rules which will be of service to the geologist in his mapping work. That nearly all of these are applicable to pure topographic work will be obvious. It will be understood also that previous training in topographic sketching is a very desirable perquisite for the geologic mappist. A knowl-

[1] This statement is intended to apply only to such areas and scales that the curvature of the earth does not produce appreciable errors. If corrections for curvature become necessary special observations for latitude and longitude may be made with the plane-table and telescopic alidade.

edge of plane-table traversing, ordinary and trigonometric leveling, and methods of taking geologic observations will be presupposed.

THE GEOLOGIST'S THREE ELEMENTS OF POSITION.

In the determination of positions on the surface of the earth, ultimately referable (for ordinary purposes) to the earth's axis of rotation, to the earth's equatorial plane, and to mean sea level, the triangulator locates with precision a few widely scattered points. The topographer connects thousands of intermediate points with the widely scattered ones and produces a topographic map which forms the base map for the geologist; or, in the absence of a topographic map, the topographer-geologist may himself begin from the triangulator's points and make his own topographic base map; or again, in the absence of beginning points, the geologist may have to measure his base lines and carry out his control of horizontal position by graphic means. The three elements of position for the geologist are (1) horizontal, (2) vertical, (3) geologic. The first two are represented upon the field map by pinhole and contour respectively, and the last one is represented by the areal and structural geologic symbols. Of these three the first, horizontal position, is the most important because the accuracy (except vertical control by direct leveling) and the correct interpretation of the others depend upon it. Good horizontal control does not necessarily imply a good map, but poor horizontal control means a poor map. Horizontal position may be given either in terms of latitude and longitude or in terms of local coördinates. Vertical position may be referred to sea level or to some local datum whose elevation is assumed. Into the geological position of a point enter the various factors of formation, structure, lithology, etc., at that place. The problem of the mapping geologist is to determine these three elements at as many points as is commensurate with the scale of the map, with its purpose, with its cost, and with the length of time available for making it. In the areas between the points definitely located these three factors should be either directly observed or readily inferable.

HORIZONTAL POSITION.

Let us consider the map as an orthographic projection of the terrane upon a horizontal plane; then in general any point in the plane may be located either (1) by a distance and an angle from a fixed point and reference line in the plane, or (2) by the intersection of two lines in the plane. Considering only straight lines the first is the method of polar coördinates and the second is the method of rectilinear (not necessarily rectangular) coördinates. Control of horizontal position by land survey lines is sometimes used, but the use of "land office control" is subject to certain difficulties, not necessarily inherent in the control, which practically preclude its use in the best work even in densely wooded areas with few prominent hills.

Determination of Horizontal Position by Distance and Angle Methods.

Under this head come all the traverse methods. Distances may be measured in a variety of ways—by tape, stadia, pacing (horse or man), odometer, range-finder, aneroid,[1] etc. The reference line for the angles at each station is usually the local magnetic meridian; less often it is a line of assumed azimuth, as in backsight traverses; and still less often it is the true meridian. The true meridian can be used, however, only with the aid of some form of solar compass adapted to the plane-table. All of the traverse methods consist essentially of (*a*) orienting the table, *i. e.*, of bringing it into its standard angular position, (*b*) drawing a line in the direction sighted, (*c*) scaling off the distance to the object sighted on the line drawn. Each station thus becomes the origin of a new polar coördinate system.

[1] For the method of measuring horizontal distances by aneroid the writer is indebted to Mr. R. H. Sargent, of the Alaska Division of the U. S. Geological Survey. It is as follows: Determine by clinometer the vertical angle between two points, and by aneroid their difference in elevation. Then the difference in elevation multiplied by the cotangent of the vertical angle gives the horizontal distance between the two points. This method is especially applicable to steep slopes, say over 15°, and to short distances, say not over one half mile.

Determination of Horizontal Position by Intersection Methods.

In general, intersection methods have the advantage of greater accuracy than traverse methods because of the lesser number of observations required. Roughly speaking, the errors are proportional to the square roots of the number of sights. Intersections can also be much more reliably checked than can traverses, as will be shown below. Intersections are very often made from plane-table traverse lines, but these intersections, especially those on distant points, may serve to adjust the traverses rather than to locate the intersected points more closely. Hence for graphic control in general good methods of intersection are to be preferred to traverse methods, however carefully the latter may be run. The analogy with geodetic control is perfect. Instrumental triangulation is more accurate than instrumental traverse, and the latter is *never* used in the most precise work.

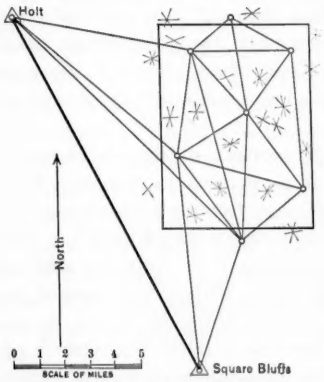


FIG. 57. Reduction of Base Line.

Base Lines.—In general the measurement of any distance involves either directly or indirectly the application of a known length in such a way as to determine the unknown length in terms of the known. In developing graphic control the funda-

mental measured line is called the "base line," or more briefly the "base." The lines derived from the base line should not be more than fifteen times its length for the best results.

In the field the geologist may have at hand for his base one or more lines joining points whose relative positions have already been determined by some instrumental survey (see Fig. 57). In such cases he should *invariably occupy the known points first,* and later occupy stations intersected from the known points. In many localities, however, he will be obliged to measure his own base line, when he will have to consider the map scale, the distance to be covered from the base, and the desired accuracy of the survey. If possible, *the base line plotted on the plane-table sheet to the field scale should not be less than two inches in length* for the reason that the errors of plotting the base become proportionally larger as the absolute length of the line representing the base on the paper becomes shorter, and this error magnified by the subsequent expansion of the base may become troublesome for bases less than two inches to the field scale. Obviously a longer base is necessary for great linear development of the graphic control system than for short linear extension, and a long base will give more accurate control over a given area than a short one.

Methods of base measure which would seem very crude to the triangulator are in most cases good enough for plane-table control. Wegemann[1] describes the measurement of a base used in the coal land classification work of the U. S. Geological Survey. This base was about 6,500 feet long and was measured with an ordinary tape, evidently without any special precautions as to slope, alignment, tension, temperature, sag, or standardization of the tape, other than that a fairly level stretch of land was used for the base. The uncertainty of such a measure may reasonably assumed to be about 1 : 1,000. The error in position arising from this uncertainty in the base would amount to about 45 feet in a survey carried diagonally across a township for a distance of 45,000 feet; or, on a scale of two inches to one mile, the error on

[1] "Plane-table Methods as Adapted to Geological Mapping," Wegemann, C. H., Economic Geology, Vol. VII., 1912, p. 621.

the paper would be less than 0.02 inch, a negligible quantity. Bases should be measured at least twice preferably in opposite directions, to eliminate possible mistakes in the tally of the tape and in the fractional reading of the tape at the end of the base. To eliminate slope errors and for ease of measurement the base should be located upon fairly level ground, although under some conditions it might be well to compute (to the nearest foot only) and apply slope corrections.

The principal system of points and lines determined from the base line is called "the graphic control net." The operation of determining the points of the graphic control net is usually divided into two fairly distinct parts, the expansion of the base, and the carrying forward of the control from the region of the base into other territory. It not infrequently happens, however, that when initial points have been located by geodetic control before the geologist begins his work the initial lines are of greater length than his detail work warrants using. Then his first sights involve a *reduction* of the base line, remembering that *the known points should be occupied first* even though they be widely separated, far out of the area to be mapped, and difficult of access. Many errors in future work may be eliminated by this precaution. Fig. 57 shows such a reduction with good check sights and a number of secondary intersections. If the known points are so far apart that they can not be plotted on a plane-table sheet to the scale used in the detail geologic mapping, a scale one half or one third as great can be used to determine a *long* line in the area to be mapped, which line can then be *very carefully* enlarged to the detail field scale on another sheet and used as the base line. After this line has been enlarged it should extend nearly across the plane-table sheet.

The Graphic Control Net.—In beginning the mapping of any new area it is well for the geologist to spend a little time in making a *reconnaissance* to select the principal stations for his horizontal net. This will eliminate the necessity of establishing check stations. A careful selection of stations will tend to reduce azimuth errors and errors due to very small angles or "thin" intersections.

Usually the principal points of the control net can be selected by taking a view from a few of the highest points in the region.

The *topography* is of first importance in laying out the sights of a horizontal system, especially if the system is to be of any considerable magnitude. For easy intervisibility, stations will in general be on the highest points; but it must not be overlooked that lower stations can often be used to advantage (see the right and left ends of Fig. 58), thus saving time and effort in climbing. In heavily timbered country, lines of sight may have to be cut on the tops of the hills used for stations, but usually a little trimming of bushes and tree branches is all that is necessary.

In laying out a control net the *intervisibility* of the stations is of course an essential consideration. Although the intervisibility obviously depends upon the topography, certain geometric conditions must be fulfilled, and the stations must be so chosen with reference to the topography that these conditions can be most economically fulfilled. In the triangle and polygon methods of control at least three points must be intervisible, and in the quadrilateral method at least four points must be intervisible. It is well also to look for long sights passing one or more intermediate stations by which to correct the orientation of the plane-table (azimuth) if angular errors happen to accumulate in the intervening work. This simple precaution is a valuable check on the accuracy of the work and may serve to adjust the survey if errors accumulate beyond the allowable limit for the scale used.

While laying out the graphic control net the geologist should also have in mind the size of the *angles* of intersection of the lines of sight, or in other words the geometric conformation of the figures in the control net. Only experience will give proficiency in choosing the best angles, but the following facts will be of service to the beginner.[1] Two lines intersecting produce a minimum error when they meet at an angle of 90°. Three lines intersecting in the same point give a minimum error when they meet at an angle of 60° or of 120°.[2] The error in position at

[1] See also "General Instructions for the Field Work of the Coast and Geodetic Survey," Coast and Geodetic Survey, 1908, p. 22 et seq.

[2] For the analytic proof of these statements see "The Elements of Precise Surveying and Geodesy"; Merriman, Mansfield, 1901, pp. 32 and 49.

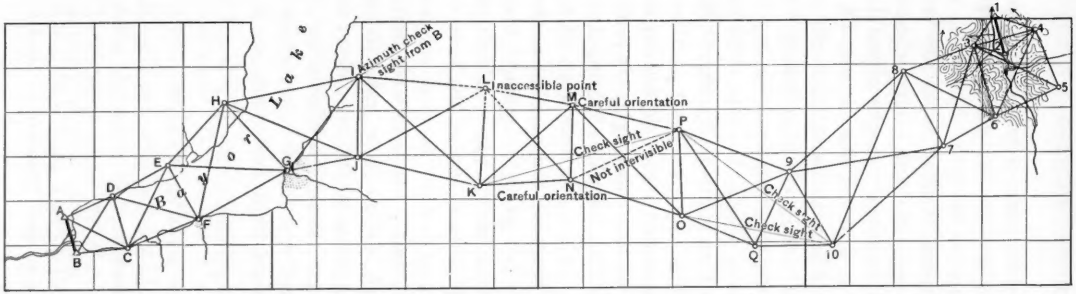


FIG. 58. A Graphic Control Net involving the commonest problems of base expansion and extension by the quadrilateral method. The squares represent square miles.

the intersection of two lines caused by errors in their directions approaches proportionally to the cotangent of their angle of intersection as that angle approaches zero. Therefore, since the differences of the cotangents of small angles are very large, the errors become very large, and "thin" intersection angles are to be avoided for position locations.[1] Angles of less than about 30° should be avoided if possible on this account, but if they are unavoidable they should have a substantial check by at least one other sight at an angle considerably more than 30° to one or the other of the lines. This condition should not be applied to the angles of azimuth check sights, however, which are used to check directions rather than positions; nor should they be applied to sights on distant objects used to adjust positions. Errors in orientation should be corrected in the field, but any errors of position with reference to the long check sights are better adjusted in the office by slightly shifting the points to bring them into accord with the check sights. This is best done when the control points are being transferred from the control sheet to the sheet to be used in the topographic and geologic mapping. In well executed work this error should not become appreciable in less than about fifteen times the length of the base from the base.

It follows that angle errors will be inversely proportional to the care exercised in orienting the plane-table and in setting up close to the center of the station (pole, stake, rock-pile). With the sights properly produced on the margins of the paper the error of a single setting of the straight edge of the alidade on the paper should not exceed 0.01 inch in one foot, or an angle of about three minutes of arc which amounts to about 4.4 feet in a

[1] For a full discussion of this point see *ibid.*, p. 49 et seq. The expression there developed is that

$$r_b = \pm br\sqrt{\cot^2 A + \cot^2 B}$$

in the triangle ABC, with the sides a, b, and c, r being the probable error of the angles (in circular measure) and r_b the resulting probable error in the side b. The expression for r_a is similar. A consideration of this expression will show that as either A or B become small, r_b approaches direct proportionality to the cotangent of the small angle, which in turn becomes very great as the angle becomes smaller. Therefore r_b becomes very large for small angles A or B.

mile. This error in sighting should be considered the maximum permissible error in a single sight and usually the mapper can do much better.

Rules of Graphic Control.—There are deduced from the above theoretic considerations and from the experience of professional mappists the following six rules of graphic control:

1. Occupy the *known* points first.

2. If a base line is measured, measure it at least *twice,* preferably in opposite directions.

3. No location is *good* unless it is made by at least *three* intersecting lines of sight.

4. Intersection angles at important stations should not be less than 30°.

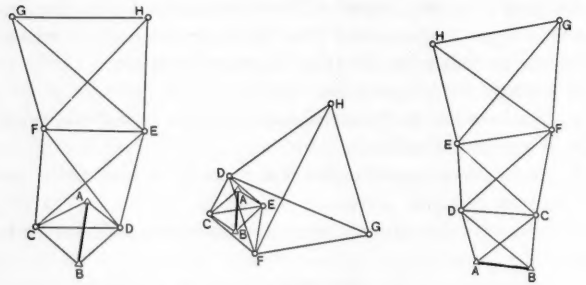
5. Orientation of the plane-table should be checked by at least *two* backsights. (This precaution is of course impossible at the ends of a base line where very great care should be used in orienting the table.)

6. Three-point locations should be made by the three nearest usable points, checked if possible by a fourth point, and the final orientation at the three-point station should be made on the farthest visible station whether it was used in making the location or not.

Methods of Base Expansion and of Carrying Forward Graphic Control.—The following statements in regard to base expansion and carrying horizontal control away from the vicinity of the base have been gathered from geometric considerations and from the experience of geodesists and topographers.[1]

The *quadrilateral method* of control involves essentially the formation of quadrilaterals beginning with the base as an element of the first quadrilateral. The base may be either a diagonal of the first quadrilateral, as shown in Fig. 59, *a* and *b*; Fig. 66 *c*; and in Fig. 58, right end; or it may be a side of the first quadrilateral as illustrated in Fig. 59 *c*, Fig. 66 *b*, and the left end of Fig. 58. The first method is slightly preferable to the second, other things being equal. The first method is especially adapted to carrying measurements from a level valley floor up into the hills or moun-

tains along the sides of the valley (see Fig. 58, right end). The expansion by this method is in the immediate vicinity of the base



a. *b.* *c.*

FIG. 59. Quadrilateral Method. *a* and *b*, expansion in the vicinity of the base; *c*, expansion by moving from the base.

line, but by using the base as a side of the first quadrilateral the base expansion proceeds away from the vicinity of the base into other territory, as along an important outcrop, a contact, a river valley, or a lake (see Fig. 58, left end). This second variety of quadrilateral control covers a greater area for a less number of stations than the first; and unless the configuration of the land prevents its use it is usually to be preferred by the geologist, especially if his base is near one side of his work. In carrying the control away from the region of the base, quadrilateral sides must be used as the bases for new quadrilaterals, and control can be thus extended in any direction desired. The method of quadrilaterals for carrying forward horizontal control is preferred in good geodetic work[2] because it gives three sights through each new point established, and the points are thus firmly held like the corners of a cross-braced panel of a bridge. For the same reason

[1] See especially the classic papers by Schott, Pierce, and others in the publications of the Coast and Geodetic Survey, and also "The Adjustment of Observations," Wright, T. W., and Hayford, J. F., 1906.

[2] See various adaptations of the quadrilateral method in "The Transcontinental Triangulation," Coast and Geodetic Survey, Special Publication No. 4, 1904.

the quadrilateral method should be used by the mapping geologist in preference to all other methods.

The topography of the region being mapped may make it advisable in some places to introduce a *polygon* (Fig. 60) into the

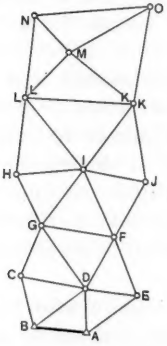


FIG. 60. Polygon Method.

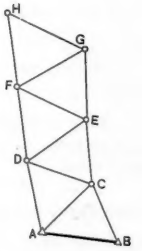


FIG. 61. Triangle Method.

control system. Its checks are not as rigid as those of a quadrilateral. The use of a polygon may in places be unavoidable if it is impossible to secure long sights for the diagonals of quadrilaterals. A four-sided polygon as shown in the upper part of Fig. 60 may be of service.[1] The polygon method was used a great deal by the early European geodesists.

The *triangle method* of control is, like the polygon method, based upon a system of two-line intersections. A triangle net (Fig. 61) may be regarded as a series of quadrilaterals with one diagonal omitted. The checks by the triangle method are therefore obviously not as rigid as those of the quadrilateral method. In the transcontinental survey executed along the 39th parallel across the United States there is but one "single but well-shaped triangle" in the whole work. The best triangle is one of 60° angles or an equilateral triangle. The use of triangles in the principal control should be avoided in good work, but if their

[1] *Ibid.*, the Missouri-Kansas Series.

use becomes unavoidable an independent check on the orientation of the plane-table should be secured by all means. This condition is illustrated in the triangle *Q*–9–10, Fig. 58, where the control is being carried from left to right. Simple triangles are very useful, however, in locating secondary points, such as houses, outcrops, test-pits, small stream forks, etc., at which no set-up is made.

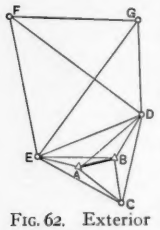


FIG. 62. Exterior Triangle Method.

The *exterior triangle method* is a curious rather than a serviceable method (Fig. 62). It is very inaccurate on account of the small angles necessarily involved and should never be used.

Under certain topographic conditions the topographer-geologist may have to resort to certain tricks in measuring his base line and in expanding it accurately.

The *auxiliary point method* (Fig. 63) is useful when two intervisible points at a suitable distance apart can not be obtained adjacent to the base line; or when some well-defined but inaccessible point lies opposite the middle of the base. (The dotted lines in the figures indicate lines of sight made *to* the station but not sighted over *from* the station.) This method is a thoroughly reliable and very useful modification of the quadrilateral method.

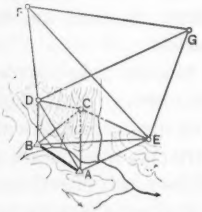


FIG. 63. Base Expansion by the Auxiliary Point Method.

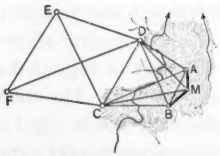


FIG. 64. Base Expansion by the Broken Base Method.

Another useful trick is used in the *broken base method* (Fig. 64). The method is especially adapted to areas of deep and irregular dissection. The figure illustrates a base measured in two

parts upon a nearly level portion of a crooked ridge. It might similarly be measured in a crooked valley where a straight line of length sufficient for a base could not be obtained. In this way a base may often be measured and expanded in most unpromising looking territory. The method of the broken base is reliable but great care must be used in drawing the angle at the middle point and in orienting on the middle point when set up at the end points. *The middle point must be occupied first.*

A rapid but rather inaccurate method of extending horizontal control is illustrated in Fig. 65. Only the base and a line of points need to be occupied. The numbers indicate the order of station occupation, and the letters the order of the intersections. The principle of the method is to locate intersections ahead of the stations and use them to resect from at the next stations. The

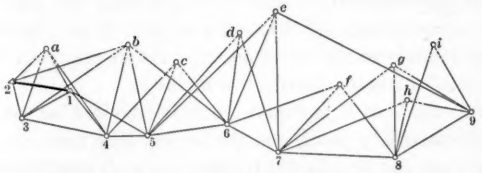


FIG. 65. The Half Quadrilateral Method of carrying forward a graphic control.

orientation must be made upon the last station occupied and checked if possible upon another occupied station. Thus, *a*, *b*, and 4 are located from 1, 2, and 3; the location at 4 is checked by a resection from *a*, but the sight 4*b* should be a check on *b* rather than on 4 because 4 is already strongly located by the sights from 1 and 3 for azimuth and position checked by the sight 4*a*. Station 5 also has two backsights, upon 1 and 4, on which to orient; but the angle 154 is weak and hence the location of 5 must be checked by a resection from *b*. The point *c* is now already determined by foresights from 4 and 5, but the angle 4*c*5 is weak, so the sight 6*c* will serve as a check upon both 6 and *c*. The plane-table at 7 is oriented by a backsight over the line 67 which was taken as a foresight from 6, and the station located by resec-

tions from *d* and *e* which have already been located from 5 and 6. 8 and 9 are similarly located from *f*, *g*, and *h*.

This method is especially adapted to making a quick and rough survey of a valley or a bay. A ridge on one side of the valley or the shore on one side of the bay can be run using unoccupied points on an opposite ridge or on the other side of the bay to make the locations at the occupied stations. The method is rapid but its sources of considerable error are several. The chief ones are the inadequate means of orientation, the dependence upon small angles for locations (cf. the angles 4*c*5, 5*e*6, and 6*f*7), and the difficulty in choosing satisfactory points for the forward stations and intersections, that is, points which can be certainly identified when the geologist comes up to them later.

Inspection of the figure will show that this method is essentially the quadrilateral method in which only one half of the stations are occupied. If the sights *ab*, *bc*, *cd*, etc., were taken, the quadrilaterals would be completed. Hence the method might well be called *the half quadrilateral method*.

Other methods of base expansion can be devised but the quadrilateral, the auxiliary point, and the broken base methods are the best, and they can be adapted to practically all conditions. The last two are in reality only modifications of the first. For carrying forward horizontal control, the quadrilateral method is the best and the polygon method is the second choice.

The *details of procedure* in the quadrilateral method are as follows. Consider the figure 66*C*. Although the control is there adapted to the scale of two inches equal one mile the procedure is the same on any scale. The plane-table is first set over one end of the base line. The point on the paper which represents that end of the base should be carefully centered over the end of the base. A plumb-bob need not be used unless the work is on a very large scale, or upon short but important sights. The geologist should so plan his control, however, that none of the orientations depend on short sights. Turn the plane-table so that the other end of the base, a_2, is in the desired direction on the paper from the end, a_1, being occupied. Sight very carefully at a_2 and

draw a_1a_2. Now without in any way disturbing the alidade or the plane-table draw short productions of this line on the extreme margins of the paper. Letter these short productions very clearly a_1 and a_2, respectively. Measure off a_1a_2 very closely to scale, being careful that the *fine* needle holes are *exactly* on the line.

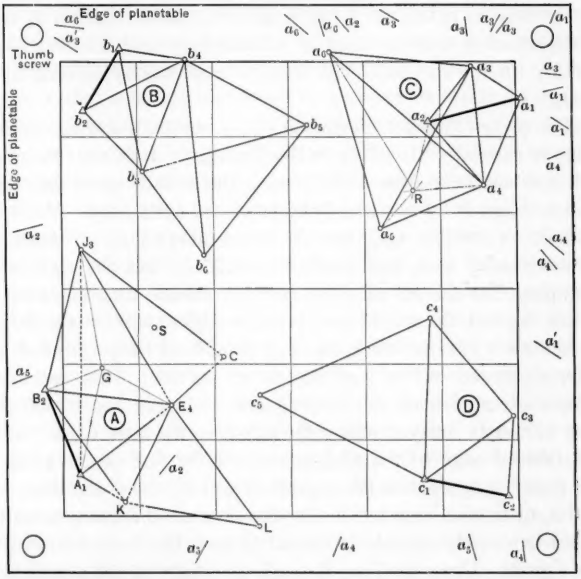


FIG. 66. Various Methods of Graphic Base Expansion and the carrying forward of Graphite Control, here shown adapted to a scale of two inches to one mile on a 15-inch square plane-table. A, the Auxiliary Point Method; B and C, the Quadrilateral Method; D, the Triangle Method.

Then with great care not to disturb the plane-table draw from a_1 the lines a_1a_3 and a_1a_4 and any secondary sights that may be deemed of possible service in the future work. Produce a_1a_3 and a_1a_4 on the margins of the paper in the same way as a_1a_2. It is evident that the long produced lines of sight will serve for accu-

rate guides in placing the alidade straight upon the lines again. Now the produced line a_1a_3, on account of its being near the corner of the paper, is too short for effective service. To obviate this difficulty a long auxiliary line, $a_1'a_3'$, may be drawn near the center of the paper, still sighting at the signal a_3 from the station a_1. These two lines, a_1a_3 and $a_1'a_3'$, are sensibly parallel, and the latter may be safely used for orientation at the station a_3 especially since it will be used in conjunction with the line a_2a_3. Before leaving this station *check the orientation* by sighting again at a_2.

The plane-table is then moved to a_2, centered, and the alidade edge is carefully placed upon the line a_2a_1. It is well to ignore the stations themselves while placing the alidade upon the paper, and to align it by means of the produced lines only. With the alidade on the line a_2a_1 turn the plane-table till a_1 on the paper points exactly at a_1 and clamp the table. Check the sight after clamping, for the act of clamping may release torsional stresses in the legs of the tripod and cause a slight twist of the board. In the most careful work the legs should all be unclamped and then tightened before any sights are taken. This seemingly simple precaution of unclamping and clamping the tripod legs may eliminate many troublesome errors in the later work. With the fiducial edge of the alidade against the fine needle stuck in the paper at a_2 sight at the signals a_3 and a_4; draw the lines a_2a_3 and a_2a_4, in each case producing the lines on the margins of the paper before the alidade is moved after it has been centered on the signals. Draw the lines through the *center* of the needle hole. A wedge-pointed pencil is the best for drawing the lines of sight but a sharp conical-pointed one should be used for lettering and for notes. Check the orientation after all other sights have been taken by another sight on a_1.

The plane-table is then removed to station a_3 which has been located by the intersection of the sights a_1a_3 and a_2a_3. Set up as before; stick the needle in the exact intersection of a_1a_3 and a_2a_3; orient on a_1 using as before the produced lines for placing the straight-edge; and check the orientation by a backsight on a_2.

The earliest sight taken at a station should control the orientation at that station and if the check sights show much discrepancy the cause of the error should be investigated at once. Take sights at a_4, a_5, and a_6, observing the usual precautions in producing the lines of sight on the margin of the paper. Check the orientation by a backsight on a_1 before leaving the station.

The geologist should then proceed to station a_4. This station should already be well located by the three sights a_1a_4, a_2a_4, and a_3a_4. Orient on the sight a_1a_4, checked by a_2a_4 and a_3a_4. It will be clear that a_1a_4 has the error of but one direction in it; and that a_2a_4 has the errors of two directions, namely, a_1a_2 and a_2a_4, in it; and that the line a_3a_4 has the errors of two directions, a_1a_3 and a_3a_4, in it. Hence in the event of a slight discordance in the azimuths of the lines coming into a_4 preference should be given to the orientation by the sight from a_1 to a_4. Sights are taken at a_5 and at a_6, and at such other stations as it may seem necessary in the judgment of the mapper to include in his control system.

The plane-table is then moved to a_5, set up, oriented on a_4 and a_3, and the locations of both a_5 and a_6 checked by the sight a_5a_6. It is the check afforded by this sight which makes the quadrilateral method the most satisfactory in developing horizontal control. If any slight discrepancy in the location of a_5 and a_6 is found to exist it should be balanced between them, but not until the station a_6 has been occupied. On the scale figured such a discrepancy should under no circumstances exceed 0.02 inch, and if the work is carefully done the three lines meeting at a_6 will meet sensibly in the same point.

Suppose now that it were desirable to locate on an outcrop at R. A three-point location should be made from the three nearest visible stations, say from a_2, a_4, and a_5, and the orientation made upon the most distant one, a_2. But if some more distant station is visible although it was not used in making the location, say a_6, the final orientation at R should be made on it. In nearly all three-point locations the lines on which the plane-table is oriented are not as long as the lines extended in the principal control on the margin of the paper, and hence the orientation at a three-

point station can not be expected to be as good as that at a station with a foresight into it from one of the principal control stations properly extended on the margin of the paper. On this account a three-point station should *never* be used as a principal station, whence follows the very important rule stated above—in beginning work, *occupy the known stations first.*

By the method of sighting as outlined above (although all of the stations were not occupied) a base of 1,475 feet[1] was carried by the writer for a distance of about five miles over a pass 2,000 feet above each end of the control on a scale of one inch equals 1,500 feet. The results in closing on the known triangle *OPQ* were as follows:

Line.	Computed Distances, Feet.	Scaled Distances, Feet.	Uncertainty in Graphic Control.
OP...	3,254.2 ±1.0	3,250	1 : 775
OQ...	2,224.2 ±1.0	2,220	1 : 530
PQ...	2,766.9 ±1.0	2,760[2]	1 : 401

[2] The article referred to above gave 2,750 feet for the scaled distance *PQ*. It should have been 2,760 feet as given in this table.

The largest error, about 7 feet, corresponds to less than one fourth of one fiftieth, or about one two hundredth, of an inch on the scale used.

VERTICAL POSITION.

Determination by Various Methods.—Although the plane-table is not primarily an instrument for determining differences of elevation it is very much used with an alidade with a vertical circle. The distances may be determined in the field by scaling from the map, and the plane-table top acts as the support for the alidade.

This trigonometric leveling should be started from a known or assumed datum for the district and transferred to the control points, and from thence by clinometer, aneroid, hand-level, or stadia traverses with vertical angles to the stations involved in the vertical mapping of the area. In some districts the relief may

[1] "The Plane-table in Detailed Geologic Mapping," Higgins, D. F., Economic Geology, Vol. VII., 1912, p. 502.

be so slight or the geological structure such that flying levels (read to hundredths of a foot) may have to be run from established bench-marks. The latter case is very uncommon and locations to within 5 or 10 feet vertically suffice in country of moderate (200–300 ft.) relief for 20-foot contours, and five times that amount can be allowed as the maximum error in heavy relief (2,000–5,000 ft.) for 50 to 500-foot contours. For details of methods and formulæ for determining differences of elevations see any standard text on surveying. An especially good discussion is in H. M. Wilson's "Topographic Surveying," under Hypsometry.

Topographic Sketching.—To indicate the conformation of the terrane and to form a proper base for the geological data the topography is indicated by contours.

"Sketching is artistic work. The power of seeing topographic forms in their proper shapes and proportions, and of faithfully transferring them to paper is one of the most difficult acquirements to obtain. The difficulty is increased by the necessity of expressing form by means of continuous contour lines at fixed intervals. This work involves knowledge of the elements of structural geology and good judgment in applying them."[1]

GEOLOGIC POSITION.

Observations on Lithology, Structure, Etc.—It is not the purpose of this paper to undertake a description of ways of recording geologic data on the plane-table sheet. Lithologic and structural symbols, formation outlines, specimen and notebook reference numbers, written notes, mine workings, etc., can all be shown on the sheet according to the taste and the judgment of the geologist. C. W. Hayes's "Handbook for Geologists" gives most complete directions and explanations for recording geologic data. A notebook will be necessary for notes too lengthy to be recorded directly on the map, for statistical data, for the descriptions of the rock specimens and their localities, for detail sketches, and for other material which can not well be placed upon the map. The plane-table is not intended to replace the

[1] Gannett, Henry, "Manual of Topographic Methods," Bull. U. S. Geol. Survey No. 307, 1906, p. 84.

notebook but to relieve it of the map drawing and to increase the accuracy and efficiency of the mapping.

Delineation of Geologic Data on the Field Sheet.—As recommended by Hayes, all the geologic data possible on the scale should be drawn directly on the field map *in the field.* The notes and the map should be brought to date not later than the evening of the day on which the observations are taken or the morning of the next day. Finished work should be inked in as nearly up to date as is practicable, that is, at the earliest daylight opportunity. If no such opportunity occurs for several days then time should be taken from the field work for inking in the field sheets. Rainy days, and Sundays, may thus be utilized. A little perspicuity in planning work will usually obviate the necessity for Sunday work, however, and the geologist will gain in efficiency by using the day as a day of rest.

The areal geology should be indicated by transparent water-color washes rather than by rubbing on colored pencil. The washes give a much neater and more workmanlike appearance than the pencils. The transparent "Japanese" tints put out by the Eastman Kodak Company for coloring photographs and lantern slides are very satisfactory indeed. The washes should be applied before any of the ink work, except the black, is done, for most of the "waterproof" colors are not strictly so and will run slightly if washes are placed over them. At the close of the field season the field sheets should be completed in every detail, ready to be assembled in the office.

COSTS.

The cost of mapping a unit of area varies about as the scale, but the amount of mining development, or the complexity of the geology, or dense vegetation may have a large influence on the cost. Open country in the west, where several horses were used, a region of rather simple geology mapped on a scale of four inches equal one mile costs about $40 a square mile. Similar work in southwestern Wisconsin, an area more broken by small drainage and more wooded than the west costs about $30 to $35

a square mile when all of the work is done on foot. A small area mapped by the writer in Korea cost about $35 a square mile when it was done in the rainy season and fully one third of the time was lost on account of bad weather. Although the use of the plane-table may slightly increase the cost of geologic mapping it is practically indispensable when the topography has to be mapped also. The gain in accuracy, in the fulness of detail possible, and in general satisfaction which may be obtained by the use of the plane-table more than offset any balance that may be thought to exist in favor of purely notebook methods.

SUMMARY.

Three elements of position may be assumed to exist for the geologist. They are: (1) horizontal, (2) vertical, (3) geologic. The horizontal position may be located by the application of the principles of either polar coördinates (traverses) or of rectilinear coördinates (intersections). In the intersection method a measured line called a base line must be used to begin the work. The system of points and lines developed from the base determines distant locations with reference to the base. This system of points and lines is called the graphic control net. The control net may be made up of various geometrical figures, of which quadrilaterals with both diagonals drawn are to be preferred. With proper precautions in manipulation horizontal control can be carried by means of the plane-table to distances fifteen or twenty times the length of the base from the base without sensible error. Vertical position may be determined in several different ways and is indicated upon the map by contours sketched to represent the configuration of the earth's surface. The geologic position is shown on the map by various more or less conventional symbols, and as much geologic information should be placed directly upon the map as is consistent with clearness and neatness. Although the use of the plane-table in geologic mapping may slightly increase the cost of the work it is far more accurate and satisfactory than the use of the notebook alone; and its results are as accurate (to the scale used) as, and much cheaper than, an instrumental survey.

ALUNITE IN PATAGONIA, ARIZONA, AND BOVARD, NEVADA.[1]

FRANK C. SCHRADER.

INTRODUCTION.[2]

Occurrences of the mineral alunite continue to be reported from time to time, most of them like those here described having been revealed during the course of regular geologic studies in mining districts by members of the United States Geological Survey. The possible economic value of such deposits as a source of potash and of alumina lends more than a purely mineralogic interest to them.

ALUNITE IN GRANITE PORPHYRY NEAR PATAGONIA, ARIZONA.

The study of certain specimens collected during a geologic survey of the Nogales quadrangle in southern Arizona in 1909 has revealed a new occurrence of alunite. The mineral occurs disseminated in an altered granite porphyry at a locality five miles south of the town of Patagonia, the specimens obtained being from the Three-R mines, which are situated in the Palmetto mining district in Santa Cruz County about 10 miles north of the Mexican boundary. Patagonia is on the Benson-Nogales branch of the Southern Pacific Railway.

Relief.—The Three-R mines are situated in the upper west slope of the north end of the Patagonia Mountains, a north-south desert range of the Great Basin type. The topography as expressed on the Nogales topographic sheet of the U. S. Geological

[1] Published by permission of the Director of the U. S. Geological Survey. A fuller account of these deposits will appear in a bulletin of the U. S. Geological Survey, entitled "Contributions to Economic Geology, 1912."

[2] In the preparation of this paper the writer has received valuable suggestions from Hoyt S. Gale, geologist in charge of nonmetalliferous deposits.

Survey is of the ruggedly mountainous character with the mountains rising steeply 2,000 feet above the valleys.

From Three-R Gulch the most feasible means of approach on the southwest the rise to the mines, which are at about 5,400 feet elevation, is about 1,000 feet in the distance of one third of a mile.

Geology.—The country rock in this part of the mountains is a medium- to coarse-grained gray granite-porphyry. It occupies a north-southerly belt about two miles wide by four miles long. The Three-R mines are near the center of the belt. The rock is composed mainly of quartz and orthoclase in large phenocrysts and their aggregates constituting more than two thirds of its volume, and in part of what seems to represent a fine-grained groundmass of the same minerals. Pyrite and chalcopyrite which seem to be primary occur in both the orthoclase and the quartz. Apatite and zircon are present as accessories.

The rock is vertically sliced by two structures or systems of sheeting of which the dominant system trends about north-south, parallel with the axis of the range and the Colossus lode, and the other about N. 75° E. Mineralized shear zones, on which mines are located, occur in both systems, and are sometimes marked by ledges with enormous croppings of which that of the Blue Rock No. 8, to the southeast of the Three-R mine and belonging to the east-west system, is an example. Also, especially in the vicinity of the north-south shear zones the rock has been pressed and sheared to a high degree, the resulting structure causing it to weather fissil like a schist, which it locally resembles. It is cut by dikes of rhyolite and a younger granite-porphyry, which intrusives, however, are only sparingly present.

The rock as shown under the microscope was probably a pegmatite but it has since been dynamically and otherwise altered principally by sericitization and kaolinization.

The Alunite.—The alunite occurs in the wall rock of the Evening Star prospect belonging to the Three-R group of copper mines which, owing to their recently discovered deposits of rich chalcocite ore, are attracting considerable attention. Here the altered

granite-porphyry instead of being sericitized and gray is alunitized and pink, and the alunite occurs chiefly as a pink replacement of the orthoclase which it almost wholly replaces so that the rock consists chiefly of quartz and alunite with a little pyrite and chalcopyrite.

The zone of alunitization extends at least several feet laterally from the vein fissure and perhaps many times this distance. It was observed only incidentally in the course of examination of the copper deposits of the mines. Its width was not investigated.

The rock in its present crushed and altered state presents a sort of graphic structure as follows: There is a general parallel pegmatitic arrangement of the minerals, quartz and mostly alunite alternating with one another in elongated crude lens-like bodies or discontinuous bands with irregular outline. These bands vary from about 0.1 to 0.4 of an inch in width. They are traversed at nearly right angles by a very close lamination or schistose-like structure amounting almost to cleavage and which is best emphasized macroscopically in the quartz. In the former feldspar areas the structure has been dimmed or alrgely effaced by the replacing aggregates of alunite which is in part pseudomorphic after the orthoclase. In or paralleling this schistose structure in the alunite or areas of the former feldspar phenocrysts occur also numerous comb-structured veinlets of alunite, by which a single crystal area is commonly sliced into 6 or 8 and some into as many as 10 or 12 sections. The veinlets are bilateral with the comb-structure locally interlocking. They are composed of slender elongated crystals which are seemingly compound, or made up of numerous smaller, almost cryptocrystalline aggregate forms, or successive zone-like stages of growth. Where the veinlets extend into the adjoining quartz they are generally less well developed.

Alunite is a hydrous sulphate of aluminum and potassium, having the formula $K_2O.3Al_2O_3.4SO_3.6H_2O$. In its pure condition, which is rare in nature, it contains 11.4 per cent. of potassa, (K_2O), 37 per cent. of alumina (Al_2O_3), 38.6 per cent. of sulphuric anhydride (SO_3), and 13 per cent. of water (H_2O).

The rock from the Evening Star prospect was found by chemical test to contain much sulphate of aluminum and potassium, and according to E. S. Larsen, who examined it microscopically and is experienced in the occurrence of alunite-bearing rocks in other fields, it is by estimate about 30 per cent. alunite and carries about 3 or 4 per cent. of potash.

The description here given is based mainly on office study of a few hand specimens collected from an occurrence which was observed only incidentally in the field and which is not shown to be of commercial value. It, however, serves to call attention to the presence of the alunite in the porphyry and suggests that as the extent of the area is not yet determined, very likely other deposits of the mineral may occur in this granite-porphyry formation which in the Three-R belt alone occupies an area of about 9 square miles and would commend itself for prospecting in event the development of the potash and aluminum industry continues, as seems assured to be the case.

The occurrence of the alunite in the granite porphyry, a post-Paleozoic hypabyssal or near plutonic eruptive, is unusual, since most of the known occurrences of alunite, especially in the western United States, are in the Tertiary volcanic rocks,[1] except perhaps that of the alunitized porphyry of Calico Peak in the Rico Mountains, Colorado, described by Cross.[2]

[1] Cross, Whitman, "On Alunite and Diaspore from the Rosita Hills, Colorado," *Amer. Journ. Sci.*, Vol. XLI., pp. 466–475, 1891, and Adams, G. I., "The Rabbit Hole Sulphur Mines near Humboldt House, Nev.," Bull. No. 225 U. S. Geol. Survey, 1894, p. 500; Cross, Whitman, "Alunite Rocks, Geology of Silver Cliff and Rosita Hills, Colorado," 17th Ann. Rept. U. S. Geol. Survey, 1895–'96, Pt. II., p. 314; Cross, Whitman, and Spencer, A. C., "The Geology of the Rico Mountains, Colorado," 21st Ann. Rept. U. S. Geol. Survey, Pt. II., 1900, pp. 92–94; Ransome, F. L., "The Association of Alunite with Gold in the Goldfield District, Nevada," Economic Geology, Vol. II., 1907, pp. 667–692; Hill, Robert T., "Camp Alunite, a New Nevada Gold District," *Engr. and Mng. Journ.*, 1908, July–December, Vol. LXXXVI., pp. 1203–6; Ransome, F. L., "The Geology and Ore Deposits of Goldfield, Nevada," Prof. Paper U. S. Geol. Survey No. 66, 1909, pp. 129–139 and 193; Butler, B. S., and Gale, H. S., "Alunite, a Newly Discovered Deposit near Marysvale, Utah," Bull. No. 511 U. S. Geol. Survey, 1912, pp. 61–63; Larsen, E. S., "Alunite in the San Cristobal Quadrangle, Colorado," Bull. U. S. Geol. Survey No. 530–*F*, 1912.

[2] *Op. cit.*, 21st Ann. Rept. U. S. Geol. Survey

The source of the alunite in the occurrence here described seems to be chiefly the alunitization of the orthoclase feldspar in the granite-porphyry by process of metasomatic replacement accomplished by hydrothermal solutions that ascended the fissure following the intrusion of the granite-porphyry itself, or perhaps the eruption of the later granite porphyry or the nearby rhyolite of Red Mountain which is abundant on the east. The solutions were probably sulphurous-acidic, and the process was attended by some silicification. The deposition apparently took place in two periods or else there was an intra-deposition crushing and shearing of the rock following which the veinlets traversing the earlier alunite bodies were deposited in the fractures. However, Ransome[1] and others have shown that the mineral may be formed under very different sets of conditions among which is the action upon feldspar as held by De Launay, and upon sericite away from free oxygen as held by Lindgren[2] of downward percolating meteoric waters charged with sulphuric acid by the oxidation of tized character of the weathered porphyry admirably fulfils the conditions requisite for the formation of the alunite by the meteoric process.

The derivation of the alunite from the granite porphyry suggests that in certain cases some of the alunite now found in volcanic rocks and which are credited as its source, may have been derived by magmatic solutions from the underlying granite or older rocks at depths where the solubility power of the solutions being at higher temperature and pressure was much greater.

Alunite in Fissures at Bovard, Nevada.

A brief visit to the Bovard district, Nevada, made by the writer in the autumn of 1911, resulted in the collection of some ore specimens from the deposits of that area in which later office study has disclosed a new and somewhat unusual occurrence of

[1] *Op. cit.*, p. 132.

[2] Lindgren, Waldemar, "The Copper Deposits of the Clifton-Morenci District, Arizona," Prof. Paper U. S. Geol. Survey No. 43, 1905, pp. 119–120, 169, 193–194.

the mineral alunite. The occurrence is wholly different from that before described near Patagonia, Arizona. The specimens referred to were obtained at the Gold Pen mine and at the Valley View prospect and similar deposits were observed in two other prospects in the vicinity of the Valley View claim.

Location.—Bovard is a small new mining district about two miles square in Esmeralda County, in southwestern Nevada. It is 17 miles south of Rawhide, a mining town, and temporarily held in 1908 a population of 1,200. It is about 20 miles northeast of Thorne, one of the nearest railway stations, from which it may be reached on the Tonopah and Goldfield Branch of the Southern Pacific Railway. But by reason of a better road which is feasible for automobiles, travellers generally leave the railroad at Shurz, whence the trip is made by way of Rawhide in a distance of about 50 miles.

Topography.—The district, as shown on the Nevada-California Hawthorne topographic sheet of the U. S. Geological Survey, which also expresses the relief of the region, lies in the northeast slope of one of the desert mountain ranges, Gabbs Valley Range, between 4,800 and 6,600 feet elevation.

The topography is mostly rough. The rise of the surface from the base of the range to the summit which is 6,624 feet in elevation, is about 1,700 feet in the horizontal distance of one and one half miles. The lower slopes are transversely trenched by deep gulches through which the drainage issues northeastward into Wild Horse Canyon.

Geology.—The rocks in the district are chiefly effusive Tertiary volcanics. They aggregate nearly 2,000 feet in thickness. Beginning at the foot of the range they consist in ascending order of dacite tuff, rhyolite, dacite and andesite. They occur in superimposed flows and intercalated tuffaceous beds which dip gently to the northeast. They are altered, faulted and fissured.

Locally in the southern part of the district where the volcanics have been removed by erosion, a small area about a fourth of a mile in diameter of the underlying Paleozoic limestone is exposed.

The limestone is dark blue or gray. It is medium to heavy-

bedded. It is much disturbed. It strikes about N. 75° W. with dip vertical or steeply to the south. It is folded, faulted, intruded by dikes of the surrounding overlying rhyolite and in places is silicified or silicated.

Mineralogy.—The mineral deposits of the district are chiefly metalliferous. They contain mainly gold with also a little silver. They occur in northwest-southeast fissures, essentially in the volcanic rocks, chiefly in the rhyolite. They in most respects are similar to the gold and silver-bearing veins which occur widely distributed in the Tertiary volcanic rocks of the west, and they apparently belong to the late Tertiary period of metallization. The gangue or filling is chiefly quartz and brecciated or crushed rock, mostly rhyolite. Much of the rhyolite has been silicified and its minerals metasomatically replaced by the infiltrated quartz and in a few instances the quartz exhibits a laminated structure and is pseudomorphic after an earlier gangue spar-mineral, calcite or barite.

In the croppings and oxidized zone the deposits are stained with or contain considerable associated limonite, hematite, chloropal, calcite, psilomelane and some ocher yellowish mineral utahite or perhaps jarosite, and in places they are sparingly bluish-streaked with molybdenite stain. Adularia is probably present associated with the pseudomorphic quartz.

The two main veins have a length of a mile and a half. Beginning on the north for the greater part of their course they approximately parallel the upper front of the range in which they lie at the elevation of about 6,000 feet. They are known respectively as the front vein and the back vein. They are spaced about 300 feet apart but diverge some toward the south. The front vein has an average width of about 10 feet and where opened in the northern part of the district at the Bovard mine by a 450-foot deep easterly 60° incline shaft, the country rock at the bottom of the shaft is still rhyolite.

Occurrence and Physical Character of the Alunite.—The alunite occurs in the form of vertical tabular sheets in the fissures in the Tertiary volcanic rocks especially the rhyolite, and in the

Paleozoic limestone. It occurs between well defined walls in association with the metalliferous veins just described and is apparently post-metalization in age. It quite regularly occupies considerable and definite portions of the main fissures, and apparently was deposited in open spaces.

The occurrence of the alunite associated with the rhyolite, broadly speaking, is geologically normal for this part of the country since most of the known occurrences of alunite, especially in the western United States, are in the Tertiary volcanic rocks,[1] which in most camps are apparently the source of the alunite.

This, however, seems to be the first instance reported of alunite occurring in Paleozoic limestone or any other sedimentary rock. It is not surprising, however, to find the alunite here, for there is apparently no good reason why it should not occur in the fissures, fractures, and bedding planes of sedimentary rocks where they are associated with alunite-bearing volcanic or other formations, which may supply the requisite materials.

The alunite has been noted chiefly in specimens obtained from the Gold Pen mine and the Valley View prospect. The true character of the mineral was not recognized in the field and little positive information can be given as to the actual extent of the deposits. In brief, the occurrence and relations of the deposits may be described as follows:

At the Gold Pen Mine.—The Gold Pen mine is located in the north part of the district about half a mile north of the Bovard mine, apparently on the same (front) vein. It is in the upper slope of the mountain and in the upper part of the geologic section. It has produced considerable high grade gold ore. It is opened by about 400 feet of work to the depth of 120 feet.

The country rock is rhyolite. It here is a pale reddish gray, fine-grained or nearly aphanitic rock and has a microfluxion structure. It consists chiefly of a cryptocrystalline or felsitic to glassy groundmass of apparently mostly feldspar and quartz in

[1] See footnote 1, p. 755.

which rest a very few larger but scarcely megascopic crystals of quartz and orthoclase and a little apatite. The rock is much altered, with the feldspar changed to and replaced by the secondary minerals sericite, kaolin quartz and feldspar. The quartz is marginally corroded, embayed and contains inclusions of the groundmass.

The vein dips steeply to the northeast. It is from 3 to 10 feet in width. It is of the fault breccia type. It is composed of finely comminuted quartz, rhyolite, and other rock breccia, all firmly cemented together by quartz. Also the contained rock fragments have been largely replaced or silicified apparently by the same solutions which introduced the cementing quartz and the gold. The vein and ore commonly show megascopic particles of free gold. The values favor the hanging-wall side of the vein with pay ore, however, generally extending from wall to wall across the workings.

As shown in the upper workings, the lower part of the mine not being enterable at time of visit, the vein is separated from the fissure wall of country rock rhyolite on either side by a tabular sheet from three inches to a foot or more wide, of whitish consolidated rock-like material locally called "dry-bone" but which examination made of an unselected specimen proved to be fairly pure alunite.

The tabular sheets in which form the alunite occurs in their relations to the vein and the wall rock of the fissure, geologically speaking, hold the position and office of gouge, but they are practically free from crushed rock, clay, quartz, iron and other foreign materials common to gouge, though in places a few grains of quartz were noted.

The alunite is massive, aphanitic and has a porcelain-like appearance. It has a hackly or conchoidal fracture and locally shows a tendency to break in lamellae parallel with the vein. It has a hardness of about 4. The color is uniformly whitish with, however, a slightly creamy or pale pinkish tinge.

At the Valley View Prospect.—The Valley View prospect is in the southern part of the district nearly a mile distant from the

Gold Pen mine. It is in the limestone area near the northeast contact of the limestone with the rhyolite and apparently is on the back vein or its fissure which after traversing the limestone reenters the rhyolite as it ascends the hill on the south.

Here on the Valley View No. 2 claim the fissure is opened by a 30-foot drift known as the lower tunnel. The drift at the face has a depth of about 40 feet. It was driven in quest of gold ore but thus far it has revealed only a little gold and silver.

Excepting some blue limestone, the most of which is silicified and very hard, the drift is almost wholly in oxidized material consisting of a blackish mixture of the minerals psilomelane, limonite and hematite which, as described, occur less plentifully in association with the metalliferous deposits in general. Throughout the length of the drift, however, in its left or east wall extends an 18-inch wide vertical tabular sheet or vein composed of a structureless or massive white substance which on being examined likewise, as the deposit at the Gold Pen mine, proved to be fairly pure alunite.

This alunite is also consolidated, very close-grained or aphanitic, but not hard. It resembles kaolin or chalk. It is friable and may be pulverized by trituration between the fingers and yields an extremely fine flour-like powder, which is smooth to the feel, much like that of talc or graphite. It differs from the alunite at the Gold Pen mine in being relatively very soft and having a low instead of a high specific gravity.

The deposit is locally parallel, streaked with a buff or pale-brownish-gray or grayish material, often with a reddish tinge which is emphasized on the slickensided surfaces and to the finger gives the same smoothness of feeling as does the white material.

The deposit is separated from the country-rock limestone by a considerable thickness of the mixture of the oxides of iron and manganese on either side as shown in the cross cuts at the end of the drift and intermediate points, and therefore apparently occupies approximately the middle part of the fissure instead of the lateral position of gouge as that at the Gold Pen mine.

The deposit at this place was not traced far beyond the drift

by which it is opened, but so far as observed it shows no indication of diminution or pinching in extent or depth.

Other Prospects.—Two lesser exposures apparently containing alunite and which have been referred to respectively as the Upper Tunnel and Mohawk prospects occur in the vicinity of the Valley View prospect last described in the limestone near the rhyolite. The material regarded as alunite in these prospects, however, is less pure than that of the Valley View prospect aforedescribed. These prospects received only a cursory field examination. No specimens were collected or examined from either of them.

Microscopic Character of the Alunite.—The powder of the alunite from the Gold Pen mine and the Valley View prospect is composed of very fine whitish or colorless crystalline grains having distinctively the rhombohedral habit of alunite and resembling cubes. The grains have a weak bi-refringence and their refractive index as determined by E. S. Larsen is 1.567 corresponding to that of alunite. They are too fine however for further determination of their optical properties. The crystalline form of the grains is best shown in the alunite from the Valley View prospect. Contained in the powder are also a few similarly fine-grained hexagonal scales which apparently are likewise alunite.

Composition of the Alunite.—The microscopic determination of the mineral as alunite was in both instances verified by chemical analyses of the specimens made by George Steiger in the Geological Survey laboratory.

The alunite from the Gold Pen mine as shown under analysis No. 27 in the accompanying table, page 763, gave approximately 36 per cent. of alumina (Al_2O_3), 33.5 per cent. of sulphuric anhydride (SO_3), and strong qualitative tests for potassa (K_2O). It also shows the presence of much water. Excepting that it is a little low in SO_3, it compares favorably with the analyses of selected samples from the Marysvale, Utah, deposit,[1] Nos. 18 and 19, and the theoretical composition of the mineral alunite.[2]

[1] Butler, B. S., and Gale, H. S., "Alunite, a Newly Discovered Deposit near Marysvale, Utah," Bull. No. 511 U. S. Geol. Survey, 1912, p. 8.

[2] Dana's "System of Mineralogy," 6th ed., p. 974.

Analyses of Alunite.

Nos. 27 and 17, respectively, are from the Gold Pen mine and the Valley View prospect in the Bovard district, Nevada.

Nos. 18 and 19 are selected specimens from the deposit near Marysvale, Utah.

	No. 27.	No. 17.	No. 18.	No. 19.	Dana.	No. 28.
Al_2O_3	36.0	38	37.18	34.40	37.0	39.03
Fe_2O_3			Trace	Trace		
SO_3	33.50	38	38.34	36.54	38.6	38.93
P_2O_5			.58	.50		
K_2O	[1]	3	10.46	9.71	11.4	4.26
Na_2O		6	.33	.56		4.41
H_2O+			12.90	13 08	13.0	13.35
H_2O-			.09	.11		
SiO_2		none	.22	5.28		
Insoluble						.50
	69.50	85	100.10	100.18	100.0	100.48

No. 28 is from Red Mountain, Colorado.[2]

The approximate composition of the alunite from the Valley View prospect is given under analysis No. 17 in the accompanying table. As shown in this analysis the mineral is relatively very pure. It is free from silica and is high in aluminum oxide and sulphuric anhydride, of each of which it carries 38 per cent., which is nearly one per cent. above the amount present in the selected specimen No. 18 from the Marysvale, Utah, deposit, and but a fraction of a per cent. below its sulphuric anhydride content. It is also one per cent. above the theoretical composition of the mineral alunite, and but .6 per cent. below its sulphuric anhydride content. Besides the constituents given in the table the mineral contains also a trace of calcite.

A distinctive feature of the mineral moreover, in this analysis, is its high sodium content which, according to Hillebrand and Penfield, constitutes the mineral a natroalunite.[3] Apparently the

[1] Gives strong qualitative tests for potassium.

[2] Hurlbut, E. B., "On Alunite from Red Mountain, Ouray County, Colo., *Am. Jour. Sci.*, 3d ser., Vol. 48, 1894, pp 1 –131.

[3] Contributions to Mineralogy from the U. S. Geol. Survey Bull. 262, pp. 38–40. 1905.

highest sodium-bearing alunite hitherto recorded in literature is that reported by Hurlbut[1] from Red Mountain, Colorado, the analysis of which is given under No. 28 in the accompanying table, page 763, and shows 4.41 per cent. sodium. Another instance in which alunite contains an almost equally high amount of sodium, 4.32 per cent., is that reported by Cross,[2] from the Rosita Hills, Colorado. Also at Goldfield, Nevada, part of the alunite contains considerable sodium. Here from Vindicator Mountain Ransome[3] reports an instance of sodium-bearing alunite in which the molecular ratio of soda to potash is as 40 to 45.

Origin of the alunite.—In most of the deposits in the western United States the alunite, like that described near Patagonia, was apparently derived from the surrounding Tertiary volcanic rocks by hydrothermal acidic solutions which in circulating through the rocks in the fractured propylitic zone became charged with the alunite constituents or raw materials which they leached from the altered potash-bearing feldspars in the rocks and later under reduced temperature and pressure and other favorable conditions deposited in various forms and places, mostly in pockets and seams in the ore deposits.

The Bovard alunite, however, was apparently deposited by magmatic solutions in which the raw material constituents of the alunite, as potassium, aluminum, sodium and sulphur, were for the most part original, and were not to any great extent derived from the adjoining consolidated rocks. This view is supported by (*a*) the considerable quantity and purity of the alunite; (*b*) the concentration of the alunite in distinctly tabular sheets or veins in the fissures; (*c*) the occurrence of the alunite in the Paleozoic limestone at a horizon considerably below that of the volcanic rocks; (*d*) the failure of cursory microscopic and chemical examination to disclose any trace of alunite in the adjoining volcanic rocks.

[1] Hurlbut, E. B., "On Alunite from Red Mountain, Ouray County, Colo.," *Amer. Jour. Sci.*, 3d ser., Vol. 48, 1894, pp. 130–131.

[2] *Ibid.*, Vol. 41, 1891, p. 473.

[3] *Op. cit.*, Prof. Paper 66, p. 131.

The apparently magmatic source of the alunite together with the greater development of the alunite deposit on the foot-wall side than on the hanging-wall side of the Gold Pen vein, and the occurrence of the alunite in the underlying limestone indicates that the depositing solutions were very probably ascending and that therefore here as at Goldfield and elsewhere the alunite deposits probably extend in depth into the sulphide zone, which in the neighboring Bovard mine is reached at about the 400-foot level. Also the occurrence of the Gold Pen deposits in the upper part, and of the Valley View deposits in the lower part, of the geologic section, indicates that the mineral probably has considerable vertical range, and that it occurs also at points between these localities. For instance, on the 200-foot level of the Bovard mine the hanging wall carries a 2-foot wide sheet of supposed gouge which was not examined in this work. It and similar deposits elsewhere probably contain alunite.

No intimacy of relationship, however, was observed between the alunite and the rich gold ore of the Gold Pen mine such as occurs at Goldfield where the alunite is a principal gangue mineral;[1] but these conditions may occur in depth.

The postmetalization, or later stages of mineralization were evidently the more favorable period for alunite deposition. And it is probable that hot springs and heated solutions from similar deep-seated sources continued to flow and circulate through the rocks during a prolonged period of waning volcanism, precipitating their mineral burdens under favorable conditions. The general absence of banding in the deposits is probably due to the extreme fineness of the material.

The recorded succession of events which led up to the deposition of the alunite is roughly about as follows:

(*a*) Intrusion and flooding of the region of deformed and eroded Paleozoic rocks by the Tertiary volcanic lavas up to the top of the rhyolite or above the present apex of the metalliferous and alunite veins;

(*b*) Fissuring of the Tertiary volcanic and older rocks;

[1] *Ibid.*, Prof. Paper 66, pp. 189–195.

(*c*) Volcanism and deposition in the fissures of veins containing calcite or some other sparry gangue;

(*d*) Volcanism attended by faulting and brecciation followed by deposition of the metalliferous veins by strongly acidic thermal solutions which dissolved out and replaced the sparry gangue and in part the fault breccia which it also silicified;

(*e*) Volcanism, faulting and re-opening of the metalliferous fissures as at the Gold Pen mine followed by ascension and circulation of magmatic solutions and deposition of the alunite in the re-opened fissures along the veins and dikes.

Conclusion.—As little is known of the extent of the alunite of the Bovard district no prediction of its commercial value is as yet justified. Furthermore, as a source of potash the outlook is not, from evidence at hand, to be considered promising. The deposit in the Valley View prospect, although it may be assumed to represent a considerable quantity of material, has been shown to consist of a potassium sodium alunite in which the potash content probably does not run high enough to be of value by itself. As to the possibility of its value as a source of alumina there is little precedent to afford a basis for an opinion. A pure alumina free from silica, if it could be derived in quantity from such a deposit, might very possibly prove of such value for the manufacture of the metallic aluminum as to justify its extraction and treatment, but this suggestion is put forth rather as a possibility than as an estimate of value which it is believed to represent.

However, in case such alunite deposits as those at the Gold Pen mine and the Valley View prospect be encountered in mining other ores it may be well to store the alunite thus encountered separately on the dump, with reference to improved facilities for its use as a by-product in the future, with the finding of further deposits in this or neighboring areas which seems likely.

SUGGESTIONS IN PROSPECTING FOR ALUNITE.

In prospecting for alunite as suggested by Butler and Gale,[1] it is well to examine (1) the generally so called kaolin and talc

[1] Bull No. 511 U. S. Geol. Survey, p. 23.

deposits and also those of jarosite, associated with the feldspathic rocks in the oxidized zone; (2) potassium-aluminum silicate-bearing forms of the Tertiary volcanic rocks where they have suffered "propylitic" alteration, as along fissures or elsewhere, by hydrothermal solutions and contain pyrite or chalcopyrite and so forth; (3) supposed spar, talc, or kaolin veins, especially in or associated with Tertiary volcanic rocks, whether or not associated with metallic veins.

PETROLEUM IN THE RED BEDS.

CHARLES N. GOULD.

INTRODUCTION.

For many years the question of the possibility of finding petroleum and natural gas, in commercial quantities, in the Kansas-Oklahoma-Texas Red beds has been of interest, both to the geologist and to the practical oil man. A number of attempts have been made to find these products in the Red beds of these three states, but until recently, none of these attempts have been successful. For many years geologists who have studied the region have believed, and apparently with reason, that the chances for finding oil or gas in the Red beds were so poor that they were unable to give encouragement to the driller.

Within the past few months considerable drilling has been accomplished in various parts in Oklahoma and Texas, and results obtained in certain localities seem to justify the belief in the possibilities of finding oil and gas in certain parts of the Red beds, which have heretofore been considered unproductive.

This article is intended to present, in brief form, certain known facts connected with the occurrence, stratigraphy, and structure of the Red beds, and to draw certain tentative conclusions regarding the possibility of finding oil and gas therein.

Throughout the greater part of the United States oil and gas are found contained in ledges of sandstone. To these ledges the driller gives the name "oil sands." There is no virtue in any sand, *per se*, but any sand which contains oil is an "oil sand." In the great Mid-Continent field of southern Kansas and northeastern Oklahoma, the greater part of the oil and gas occurs in standstones of Pennsylvanian age, interbedded between shales and clays. Occasionally oil is found in a porous limestone. It is probable that any oil which may eventually be found in the

Permian Red beds, which lie above the Pennsylvanian, will be contained in sands. Three questions then arise, viz.:

1. Are there, in the Red beds of Oklahoma and Texas, sands of sufficient thickness to contain oil and gas in paying quantities?

2. If such ledges do occur, where are they located?

3. Is there sufficient evidence of structure in the Red beds to determine the most likely places in which to drill?

In the Mid-Continent oil field, the greater part of the oil and gas so far developed occurs either along anticline folds, or at least in localities where the normal western dip of the rocks has been interrupted, and the rocks are found to lie comparatively level, forming terraces, or "arrested anticlines." If, beneath an anticline, or a terrace, there occurs a particularly thick ledge of sandstone, there oil and gas usually occur in paying quantities. It is then of the utmost importance to locate with the greatest possible accuracy any anticline or other evidence of structure, in the Red bed rocks. These are the problems to be discussed in this article.

AREA.

The term Red beds, as usually understood, is applied to a series of brick-red shales and clays, containing certain interbedded strata of some other rock, occupying an area of approximately 50,000 square miles in southwestern Kansas, western Oklahoma, and northern Texas, and extending thence westward to the Rocky Mountains. The northern extent of the area, so far as known, is near Hutchinson, Kansas, the eastern margin is near Shawnee and Chandler, Oklahoma, the southern limit near San Angelo, Texas. The greater part of these Red beds are of Permian, or Upper Carboniferous age, and rest directly (usually conformably) above the Pennsylvanian or Coal Measures rocks, to the east. In east-central Oklahoma there is an area of Upper Pennsylvanian rocks, which, so far as color and stratigraphy are concerned, are typical Red beds. In the western parts of the States mentioned, the Red beds have been covered by other formations of a later geological age, either Cretaceous, Tertiary, or Pleistocene. With the exception of the mountain areas hereafter to be

described, there is no place in southwestern Kansas, western Oklahoma, or northern Texas, however, where the drill, if carried deep enough, will not penetrate the Red beds.

ORIGIN.

The problem of the origin of the rocks which make up the Red beds has not been definitely solved. There are, in North American geology, very few more perplexing problems than that of the origin of the Red beds. There is considerable evidence which would seem to indicate that the rocks of the Red beds were, in part at least, wind-blown or of desert origin. On the other hand, in many parts of the series ledges of sandstone and dolomite contain typical marine fossils. Other fossils which are common in certain localities are remains of fresh water forms. Some of the earliest known reptiles and many primitive amphibia occur as fossils in the Red beds rocks. These various forms of extinct animal life have been studied and described by Cope, Williston, Beede, Case and others.

During late Pennsylvanian and Permian times there were, in and around the region now occupied by the Red beds, several land masses, to which we may look as a possible source of material for these formations.

There is geological evidence to the effect that during Pennsylvanian times, both the Wichita and Arbuckle Mountains, which are now ranges averaging 60 to 80 miles long, and 20 to 30 miles wide, were elevated until they stood 2 to 3 miles above their present level. It is also evident that much of the erosion of these land masses occurred during late Pennsylvanian and Permian times. That is to say, two land masses, each more than 60 miles long, 25 miles wide, and 2 miles thick, were worn away during late Pennsylvanian and Permian times, and spread out over a considerable part of the area now occupied by the Red beds. In other words it is to the old Arbuckle and Wichita Mountain systems that we must look for a considerable part of the deposits which now are included in the Red beds.

Other possible sources for the materials now constituting the

Red beds may be sought in the Ozark Mountains of Missouri, the Llano-Burnett region, or "Central Texas Mineral Region" of Texas, the Rocky Mountains of Colorado and New Mexico, and a hypothetical land mass, which probably extended from the eastern end of the Arbuckle Mountains across southeastern Oklahoma, possibly into northeast Texas.

A study of these possible sources for rocks which constitute the Red beds, will give some idea of the conditions which must have existed during Permian times. Streams from the Arbuckle and Wichita Mountains deposited their loads of sediments in what is now southwestern, central and northwestern Oklahoma, and northern Texas. At the same time other streams having their sources in the Ozark Mountains, passed westward across Oklahoma, and left sediments in the northern part of the state. Still other streams from the Llano-Burnett region, and other land masses, carried sediments into various parts of the Permian seas.

All of these sediments consisted in a considerable part of sands. The mountain areas, above named, consist largely of granites, porphyries, and other siliceous rocks. These sediments were spread out along the old ocean beach in the form of sand bars, often of considerable thickness and areal extent. These bars were afterwards consolidated into sandstone, which would undoubtedly form a suitable reservoir for the storing of large quantities of oil or gas. In point of fact, there is no part of the Red beds where sandstones may not be found. At least two of the formations of this series in Oklahoma, the Woodward and the Quartermaster, are composed largely of sandstones.

STRATIGRAPHY.

While the general term Red beds is applied to all of that great series of shales and interbedded rocks of Permian and Upper Pennsylvanian age, extending from southern Kansas to central Texas, it must not be understood that the stratigraphy of all parts of the series is the same. In point of fact there is considerable difference in the stratigraphic succession in the northern part and the southern part of the area occupied by the Red beds. The

main line of division of these two areas may be roughly drawn at the Arbuckle and Wichita Mountains. The general stratigraphy of the two separate regions, and the probabilities of finding oil therein, will be discussed separately.

STRATIGRAPHY OF THE NORTHERN AREA.

It is not my intention at this time to enter into a detailed geological discussion of the stratigraphy of the rocks of the northern part of the Red beds area. Suffice it to say that many geologists have, at various times, studied and described the rocks, and have given individual names to the various beds. Some fifteen years ago, Cragin classified the Red beds of southern Kansas, under the term Cimarron series, dividing them into a number of different formations, composed of shales, sandstones, gypsums, and dolomites. Prosser afterward modified Cragin's classification. In Oklahoma the Red beds have been divided into six formations, namely, the Chandler, Enid, Blaine, Woodward, Greer and Quartermaster. Of these the Chandler beds are Upper Pennsylvanian, the others Permain, in age.

The distinguishing characteristic of all the Red beds formations is the intense brick-red color of the greater part of the rocks, which consist for the most part of rather soft clays and clay-shales. In many localities there are, however, interbedded with these clay-shales, certain well-defined ledges of soft sandstone. The Chandler and Enid formations contain several sandstone ledges, 20 to 50 feet thick. The Whitehorse member of the Woodward formation, which is composed entirely of sandstone, varies from 50 to 75 feet in thickness. The Quartermaster formation, 300 feet thick, is largely sandstone and sandy shale.

One point which must always be kept in mind in discussing the Red beds is that the base of the series is not a sharp line. That is to say, there is, in most places, a gradation from the non-red rocks of the underlying Pennsylvanian to the brick-red shales and sandstones of the Red beds. The Pennsylvanian or Coal Measures rocks which lie to the east of the Red beds consist of alternating ledges of gray to brown sandstone, various

colored shales, and limestones, with occasional beds of coal. The limestones, of the Pennsylvanian series, are most abundant in southern Kansas and northern Oklahoma, and gradually thin out and disappear to the south, usually in the region of the Arkansas River.

On coming westward and approaching the eastern margin of the Red beds, the color of the surface formations gradually changes. The shales which throughout the greater part of the Pennsylvanian area are predominatingly blue or drab in color, become maroon or red. For a number of miles, however, only occasional ledges of red shales are found. The sandstones here are gray, brown, or yellowish in color. On passing still farther westward the color of the rocks changes more rapidly until soon all of the surface shales are red or maroon in color, and the sandstones have changed from gray to red or light brown. Still farther west all the rocks, both shales and sandstones, are deep brick-red. It will thus be understood that the line of demarcation of the base of the Red beds cannot be sharply drawn because of the fact that on coming westward the change from non-red to red sediments is gradual.

Structure in the Northern Area.

There is little data on which one may base the determination of structural features in the northern part of the Red beds. The lenticular nature of the sandstone, and the prevalence of cross bedding often gives the appearance of anticlines, but careful observation will usually demonstrate the error of such conclusions. So far as I know, after fifteen years careful study of the subject, there are very few anticlines or synclines in the Red beds of central or northwestern Oklahoma, or southern Kansas.

Oil in the Northern Area.

Practically all the oil so far found in the Mid-Continent Field, in northeastern Oklahoma, occurs in formations which lie at depths varying from 1,500 to 3,000 feet below the base of the Red beds. The most productive oil sands, particularly in the

northern part of the field, occur in the Cherokee shales, which lie at the base of the Pennsylvanian series.

There are in many of the oil pools already developed two or more productive oil sands. For example, the Cleveland pool has five producing sands of which at least three are found in formations above the Cherokee shales. The Bartlesville pool, for instance, has seven producing sands with four above the Cherokee shales. In both the Ponca City pool and the Cushing pool, the two which lie nearest the eastern margin of the Red beds, the greater part of the development is from sands higher in the Pennsylvanian series than the Cherokee shales. Up to the present time, however, so far as known, nowhere, in northern or eastern Oklahoma, has a productive oil sand been found either in the Red beds rocks or within several hundred feet beneath the base of that series.

This leads to two very interesting and important questions, namely: the thickness of the Red beds in various parts of Oklahoma and Kansas, and the depths beneath the Red beds at which oil-bearing formations occur. These questions are not always easy to answer. It should be remembered that throughout the entire region west of the Grand River, in northern Oklahoma and southern Kansas, the normal dip of the Pennsylvanian rocks is to the west or northwest. This dip averages 30 feet to the mile from Grand River west as far as Creek and Osage counties. From that point west the dip gradually diminishes, until in a region occupied by Grant, Garfield, Kingfisher, Canadian and Grady counties, Oklahoma, the rocks seem to lie approximately level. In the western part of the state, the dip of the rocks is to the east, averaging about the same as the slope of the surface, that is, 6 to 8 feet to the mile. In other words, there is, in central Oklahoma, a broad synclinal trough, with its axis extending from Grant to Grady counties, toward which the rocks dip from both east and west.

In the region occupied by the eastern margin of the Red beds as outlined above, the dip of the rocks averages about 20 feet to the mile to the west. In the same region, the surface slopes east

approximately 6 feet to the mile. By taking into account the average dip of the rocks to the west, and the average slope of the surface to the east, we may arrive at a somewhat approximate conclusion as to the thickness of the Red beds at any particular place. For example, Oklahoma City lies about 55 miles west of the nearest point on the eastern margin of the Red beds. Taking 26 feet to the mile as the combined dip and slope, it will readily be seen that the Red beds should be about 1,650 feet deep at Oklahoma City. In point of fact in a deep well at Spencer, twelve miles east of Oklahoma City, the drill passed through the last of the Red beds at about 1,550 feet. At El Reno, twenty-five miles west of Oklahoma City, a well recently drilled 3,315 feet deep encountered the last of the typical Red beds at about 2,000 feet. This well showed no sand below the base of the Red beds.

Deep drilling in other places in this part of the State has demonstrated that the thickness of the Red beds throughout some half dozen of the central counties varies from 1,200 to 2,000 feet. Below this depth the character of the rocks changes, the shales become bluish and drab in color, and the sandstones, if present, are usually gray or brown, conditions typical of the underlying Pennsylvanian formations. In other words, the same gradation of sediments is encountered in these deep wells as occurs on the surface along the region occupied by the eastern outcrop of the Red beds.

Throughout this part of Oklahoma, that is to say in central and northwest-central Oklahoma, deep wells in search of oil and gas have been drilled at a number of points, including Chandler, Meridian, Guthrie, Mulhall, Perry, Shawnee, Spencer, Purcell, El Reno, Ninnekah, Chickasha, Kingfisher and Rusk. These wells have varied in depth up to 3,300 feet. Small quantities of oil and gas have been reported in a few of these wells but nothing of commercial importance has ever been encountered.

A well 3,381 feet deep, at Alva, in the northern part of the state, passed through the Red beds at about 1,100 feet, encoun-

tered the limestones which outcrop on the surface near Newkirk, Oklahoma, and Arkansas City and Winfield, Kansas, at about 1,700 feet. Small amounts of gas were reported near the bottom of this well. Drilling in the Red beds near Medicine Lodge, Kansas, a number of years ago, to a depth of approximately 2,000 feet, revealed nothing of importance.

Taking into consideration the facts just stated, therefore, it would seem that, at the present time, there is little to encourage the hope of securing oil or gas, in paying quantities, in the Red beds of central or northwestern Oklahoma, or southern Kansas, unless it be possible to carry the wells to a sufficient depth to encounter sands in the Pennsylvanian rocks, which produce the oil in such fields as Cushing, Cleveland, and Ponca City. From what has preceded, it will be evident that these sands are deep seated.

Stratigraphy of the Southern Area.

South of the Wichita and Arbuckle Mountains, in the country along the Red River, and from that stream southward, the stratigraphy of the Red beds is somewhat different from that in the area, heretofore discussed, north of the mountains. The chief distinction is that the formations of the southern area, particularly near the mountains, contain a larger amount of sandstone. These sandstones are more or less lenticular, and consist usually of rather coarse sand and small pebbles. In many instances the sands are distinctly conglomeratic. The pebbles which make up this conglomerate consist usually of quartz, granite or limestone, evidently derived from the mountains. It is noted that near the mountains the sediments are relatively coarse, while at a distance from the mountains they become finer. These sandstones dip away from the mountains, disappearing under higher rocks, usually red shales. In many cases the truncated edges of the sandstone ledges near both the Wichita and Arbuckle Mountains contain semi-liquid asphalt, and liquid asphalt or heavy oil is found in many shallow water wells drilled in this region.

Oil in the Southern Area.

The greater part of the oil so far found among the Red beds of Oklahoma and Texas, is in the country contiguous to the Wichita and Arbuckle Mountains, and at a distance of not to exceed 50 miles from these ranges. As stated above, very little petroleum or natural gas has yet come to light in the region north of the Arbuckle and Wichita Mountains in western or central Oklahoma. Exceptions are to be noted near Gotebo, Hobart, and Granite, on the north flank of the Wichita Mountains where limited amounts of both oil and gas have been found.

Conditions south of the mountains are quite different. There are at least seven distinct localities within 50 miles of the Wichita and Arbuckle Mountains, where considerable quantities of both petroleum and natural gas have already been produced. Three of the localities, namely, the Electra, Burk Burnett and Petrolia pools, are located in Texas, less than ten miles south of Red River. Of the others, which are in Oklahoma, the Wheeler pool is located about ten miles south of the Arbuckle Mountains; the Loco pool some twenty miles southwest of the Arbuckles; the Duncan pool about half way between the Wichita and Arbuckle Mountains, and the Lawton pool some ten miles southeast of the Wichitas.

In all of these productive fields the conditions of stratigraphy are very similar. The surface is occupied by ordinary red clays and sandstones. The sandstone outcropping on the surface often contains asphalt, which frequently forms springs. The drill penetrates successive alternating layers of red shales and sands. At depths varying from 500 to 1,500 feet beneath the surface, the general color of the rocks changes from red to blue, and darker colored shales becoming more prominent. In several wells limestones are encountered at about 1,000 feet.

Throughout this general region one marked peculiarity of the stratigraphy should be noted, namely: the great number and general lenticular nature of the oil sands. In the Wheeler pool, there are at least five productive sands, the deepest of which lies at about 1,000 feet. In wells near Duncan and Loco, six to eight

sands have been found in wells, above 1,500 feet, all of which produce small quantities of oil and large amounts of gas. In one of these wells at Loco a sand at 690 feet is reported to yield 15,000,000 cubic feet of gas per day, while another well 400 feet deep is said to produce 60 barrels of oil daily. In the Petrolia pool, there are from five to eight producing sands, the deepest of which is 1,750 feet beneath the surface. The number of sands in the Electra pool varies in different wells, but at least eleven sands have produced oil in that region, the deepest of which is 1,960 feet. These sands are usually quite lenticular so that it is often possible to encounter a certain productive sand in a well, while in other wells near at hand no sand is found at that depth.

All of this is to say that the conditions of stratigraphy in this region south of the Arbuckle and Wichita Mountains are such as to warrant the belief that continued drilling will reveal the presence of many additional pools which will yield very large amounts of oil and gas.

Relation to Structure.

Studies which have recently been made by several geologists have demonstrated that there are, in this general region, a number of small irregular anticline folds, or regions of disturbance. Udden, in his recent report on the geology of the oil fields in northern Texas, inclines to the belief that there is evidence of an anticline at both the Petrolia and Electra pools. Careful studies made in the Wheeler pool seem to indicate that the same conditions obtain there also. The work of Munn, under the direction of the United States and Oklahoma Geological Surveys, in Cotton and Tillman counties, Oklahoma, has demonstrated that there are several areas of anticline folds in that general region. There are undoubted indications of anticlines near the Loco and Duncan pools, in the country south and west of the Arbuckle mountains, in Carter, Jefferson and Stephens counties, Oklahoma. There are doubtless many other localities, yet unknown, that contain evidences of anticlinal structure.

It must not be understood that the structure of the rocks in

these localities is easy to determine. In fact, in many cases, it is most baffling. Exposures are usually rare and ledges of rocks hard enough to serve as markers are often wanting, while the heavy accumulation of soil often effectively conceals the structure.

Notwithstanding these unfavorable conditions, however, enough preliminary work has been done, by different individuals, in several widely scattered areas in this general region, to demonstrate that there really is, in this part of the Red beds area, geological structure sufficient to warrant the belief that if "wildcat" wells are properly located, the risk incident upon the development of new territory will be considerably minimized, and the chances for finding petroleum and natural gas, in paying quantities, greatly increased.

CONCLUSION

The extent of the area within which one may be justified in spending money in testing for oil and gas in the southern part of the Red beds is as yet unknown. In the light of present knowledge that part of Oklahoma lying between the Arbuckle and Wichita Mountains, on the north, and the Red River on the south, seems to be by far the most favorable. That is to say, certain parts of Carter, Love, Stephens, Jefferson, Comanche, Cotton, Tillman, Kiowa and Jackson counties, Oklahoma, may be prospected with profit. There should also be included all, or parts, of Montague, Wichita, Clay, Archer, Wilbarger and Hardman counties, Texas. A number of wells yielding oil or gas, in rather small quantities, have been found as far south as Brown and McCullough counties, Texas, and there need be no surprise if the region between these counties and the Red River eventually yield considerable amounts of these products.

Throughout this general region, however, it will certainly be the part of wisdom to have the locality contiguous to a prospective well carefully studied by competent geologists, before attempting to drill. Throughout this general region drilling is expensive. One can scarcely expect to complete a "wildcat" well to

a depth of 2,000 feet for less than $10,000. In fact wells in this region have cost all the way from $15,000 to $20,000 and without results.

The geologist who works in this region will be confronted with many difficulties. The definite location of such anticline folds as may exist will not be easy, often impossible. Days, perhaps weeks, may be required in a limited area in order to endeavor to locate the structure. Even after having spent this time, only negative results may be secured.

It is, however, the belief of every practical geologist, who has visited the region, that there is sufficient structure which may be determined from the surface to materially aid the driller in the location of wells. The work done by the United States Geological Survey, the department of economic geology of the University of Texas, and the Oklahoma Geological Survey, in attempting to solve the structural problems in this region, before the oil fields have become ancient history, is to be commended. If the practical oil men will be guided by the findings of these surveys, much valuable time and vast amounts of money will be saved.

UPWARD SECONDARY SULPHIDE ENRICHMENT[1] AND CHALCOCITE FORMATION AT BUTTE, MONTANA.

AUSTIN F. ROGERS.

Though first hinted at by Gonzalo y Tarín[2] in his monograph on Huelva, in 1888, and by Fuchs and de Launay,[3] in 1893, the development of the idea of secondary sulphide enrichment is the result almost entirely of the observations of American geologists and constitutes perhaps the most important American contribution to the theory of ore-deposits.

The pioneer papers of S. F. Emmons,[4] Weed,[5] and Van Hise[6] appeared almost simultaneously in the same year (1900). Ransome's[7] valuable paper on "Criteria of Downward Sulphide Enrichment" was followed by interesting discussions by Foote, Gregory, Keyes, Louis, Sales, Wells, and A. N. Winchell in volume five of ECONOMIC GEOLOGY. An excellent short summary of secondary sulphide enrichment (with bibliography) by Tolman[8] appeared early in 1913, and recently a comprehensive summary of the whole subject by W. H. Emmons[9] has been published by the United States Geological Survey.

[1] The objection to the use of the term has been pointed out to the writer by Prof. C. F. Tolman and Prof. W. H. Emmons. Prof. Emmons suggests *deep-seated metasomatic development of chalcocite*, but for the sake of argument the term as given is retained.

[2] Reference cited by Becker in Emmons' volume on Ore Deposits, p. xxxix.

[3] "Traité des Gites Minéraux et Metalliferes," Vol. 2, pp. 230–234.

[4] "The Secondary Enrichment of Ore-Deposits," *Trans. Am. Inst. Min. Eng.*, Vol. 30, pp. 177–217.

[5] "Enrichment of Mineral Veins by Later Metallic Sulphides," *Bull. Geol. Soc. Am.*, Vol. 11, pp. 179–206.

[6] "Some Principles Controlling the Deposition of Ores," *Trans. Am. Inst. Min. Eng.*, Vol. 30, pp. 27–177.

[7] ECON. GEOL., Vol. 5, pp. 205–220, 1910.

[8] *Mining and Scientific Press*, Vol. 106, pp. 38, 141, 178, 1913.

[9] "The Enrichment of Sulphide Ores," Bull. 529, U. S. Geol. Surv., 1913.

As usually defined, secondary sulphide enrichment refers to the enrichment of sulphide minerals by descending, cold, acid (or possibly neutral) waters. It is usually explained by the action of soluble sulphates of the oxidized zone upon the unaltered sulphides below.[1]

In a recent study of a disseminated copper ore from a mine in Plumas County, California, the name and location of which must be withheld for the present, the writer came to the conclusion that one of the ore-minerals, chalcocite, which appears as rims around the bornite, was formed by ascending, rather than by descending, solutions.

The ore-minerals in this Plumas County mine include magnetite, hematite, bornite, chalcopyrite, and chalcocite. They

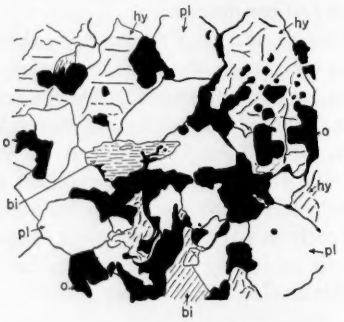


FIG. 67. (×25 times.) Norite-diorite from Plumas County, California. O = Ore minerals; hy = hypersthene; pl = plagioclase; bi = biotite.

are disseminated through a norite-diorite (consisting of plagioclase (AbAn), hypersthene, diopside, hornblende, biotite, and chlorite with accessory apatite, titanite, interstitial quartz, analcite, and epidote) in such a way as to indicate that they have been formed at the end of the magmatic period by pneumatolytic[2]

[1] Grout (ECON. GEOL., Vol. 8, pp. 407–433, 1913) has recently advanced the view that the sulphides of the secondary enrichment zone may be formed by the interaction of soluble sulphates from above with alkaline solutions from below.

[2] I use this word in a general sense, not in its original restricted sense.

agents which have deposited their metallic contents by a partial replacement of the silicate minerals. Fig. 67 is a drawing of a thin section showing the relation of the ore-minerals (mostly hematite and magnetite in this case) to the hypersthene, biotite and plagioclase. The replacement of the silicates by ore-minerals is unmistakable (see especially biotite at the left-center of the drawing). This is a magmatic sulphide ore but it may be classed under the "Gîtes de immédiat depárt" of de Launay,[1] for which there is no suitable English equivalent. The silicate minerals in these Plumas County ore-bearing rocks are (for the most part) perfectly fresh. The replacement of the feldspars and other silicates has not been accompanied by silicification, or kaolinization, or by sericitization to any great extent[2]. What little hydrothermal alteration there is, is almost certainly independent of the ore-deposition, though there are evidences that hornblende was formed from diopside and chlorite from biotite by pneumatolysis. It is in no sense comparable to the disseminated mineralization of the so-called porphyry coppers of Bingham and Ely.

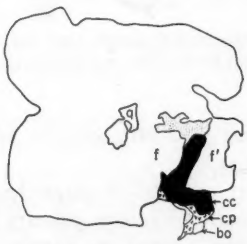


FIG. 68. (×25.) Primary chalcocite (cc), bornite (bo), and chalcopyrite (cp) in feldspar (f). q=quartz. Plumas County, California.

A complete description of this interesting ore-deposit will be presented in a future paper. For the present I will simply present the evidence which points to upward secondary sulphide enrichment. Fig. 68 (from a granodiorite or quartz-monzonite

[1] "Gîtes Minéraux et Metalliferes," Vol. I, p. I, 1913.

[2] In the only slide of the suite which contains tourmaline the feldspars are in part sericitized and in part perfectly fresh.

variant of the main rock-type) shows chalcocite[1] which, together with bornite and chalcopyrite, have partly replaced a feldspar crystal, for the two portions of the feldspar, *f* and *f'*, are in optical continuity.

The secondary chalcocite is found in five different specimens as rims around bornite principally. In Fig. 69 primary bornite and chalcopyrite have replaced biotite and the secondary chalcocite occurs around the bornite and to a slight extent around the chalcopyrite. In this specimen the biotite and plagioclase are perfectly fresh. The only possible mineral which may be called

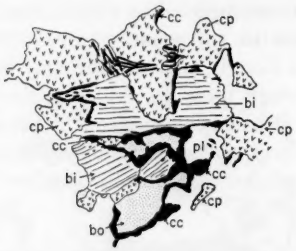


FIG. 69. (×25.) Primary chalcopyrite (cp) and bornite (bo) and secondary chalcocite (cc) with biotite (bi) and plagioclase (pl). Plumas County, California.

an alteration product is a little chlorite and it is probably a pneumatolytic mineral.

Another specimen consists of plagioclase, quartz, chlorite, tourmaline with primary magnetite, primary bornite and secondary rims of chalcocite around the bornite. The evidence of pneumatolysis is clear in this case. The chlorite has probably been formed from biotite, though there are no remnants of biotite left. The plagioclase is in part fresh and in part sericitized. There is evidence that this is oxidized ore.

In another specimen, consisting of perfectly fresh plagioclase, hornblende and biotite with magnetite and hematite, there was found a piece of compact chalcocite with a core of bornite. This

[1] This was first thought to be original chalcocite but a study of the polished section seems to show that it may be secondary.

specimen came from a soft seam, but there was no evidence of oxidation.

Narrow one-inch pegmatite veins consisting of plagioclase (albite) quartz, titanite, apatite, epidote, chlorite and calcite contain chalcopyrite and a little bornite as primary constituents. Fig. 70 is a sketch of bornite with secondary rims of chalcocite from one of these pegmatites. The constriction in the lower part of the right-hand sketch of Fig. 70, the embayment of chalcocite in the upper part of the left-hand sketch, and the isolation of bornite in spots is conclusive evidence that the chalcocite was formed, in part at least, at the expense of the bornite and not simply as a deposition around the bornite.

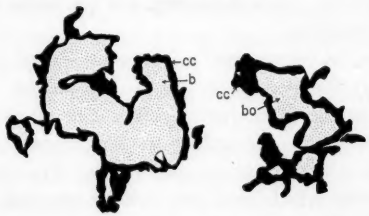


FIG. 70. (×25.) Secondary veins of chalcocite (cc) around bornite (bo) in pegmatite. Plumas County, California.

In still another specimen, with a high copper content, chalcocite occurs as rims around bornite. In this case the positive identification of the chalcocite is based upon a chemical analysis of selected rock chips made by Mr. G. W. Jordan, chemistry student at Stanford University. His results are as follows:

	Mol. Ratios.
Cu = 43.95	0.691
Fe = 5.12	0.109
S = 14.15	0.472

A mixture of fifteen parts of chalcocite (Cu_2S) and eight parts of bornite (Cu_5FeS_4) is necessary to account for the high copper to sulphur ratio indicated by the analysis. As chalcopyrite is absent in the slide and as a nitric acid solution was taken.

the analysis, on recalculation, proves that the chalcocite contains iron (about 6 per cent.).

There are three possible methods of formation of the chalcocite rims.

1. Simple deposition (primary enrichment).
2. Descending secondary sulphide enrichment.
3. Ascending secondary sulphide enrichment.

As the chalcocite is formed at the expense of the bornite (see Fig. 70) the first method of formation may be dismissed.

Whatever its source, the chalcocite is a secondary[1] mineral. The question remains as to whether the formation of the secondary chalcocite was caused by downward-moving, cold, oxidizing, acid solutions or by upward-moving, hot (or warm), non-oxidizing, alkaline solutions.

Aside from the microscopic evidence presented, the geological evidence kindly supplied me by Mr. H. W. Turner, of San Francisco, points to the formation of chalcocite by ascending solutions of some kind. According to Mr. Turner there are no strong persistent fissures or crushed zones. The only fissures in the norite-diorite which have any evident connection with mineralization are the narrow pegmatites mentioned above. Most of the fractures observed are post-mineral. Joint-seams are numerous but, as far as examined, they do not contain sulphides. Near the surface the fractures and joint planes contain chrysocolla. No effects of dynamic or contact metamorphism are apparent.

Of the five specimens containing secondary chalcocite, three have no possible connection with oxidation. Of the other two, one (Fig. 69) contains perfectly fresh biotite and plagioclase. This specimen occurs just below a seam along which there was, according to Mr. Turner, some oxidation by surface waters. The presence of oxidation near this seam is probably a coincidence, for the specimen with tourmaline shows much more alteration (sericitization) and it occurs without any possible connection with oxidizing surface waters. In the case of the chalcocite in the pegmatite (Fig. 70) there seems to be no possible con-

[1] I use *secondary* in a mineralogical sense.

nection with oxidation. The calcite, chlorite, and epidote which occur in the pegmatites are not alteration products, though they are the last minerals to be formed (probably at comparatively low temperatures from solutions).

Both the geological evidence and microscopic evidence, especially the freshness of the silicate minerals, the absence of silicification and kaolinization, and the absence of porosity, are opposed to the idea of downward sulphide enrichment by sulphate waters. There remains to be considered secondary sulphide enrichment by ascending solutions which were probably alkaline. Copper sulphide is somewhat soluble in ammonium sulphide. The compound $(NH_4)_2S_5 \cdot 2CuS$ or $(NH_4)_2Cu_2S_4$ is known, as are also $Na_2S \cdot 2CuS \cdot Cu_2S$ and $K_2S \cdot 2CuS \cdot 3Cu_2S$.[1] The possibility of copper acting as an acid-forming element is shown by the above compounds as well as by double salts such as $CuF_2 \cdot 2KF$ and $CuCl_2 \cdot KCl$. A potassium cuprate is said to have been prepared by Fremy. It is possible to write various equations which furnish Cu_2S (chalcocite) by the action of alkaline sulpho-salts upon Cu_5FeS_4 (bornite) but in the absence of experimental proof it is hardly advisable.

The primary ores of the Plumas County norite-diorite were probably formed by gases or pneumatolytic vapors which deposited their metallic contents by replacing the silicate minerals. The secondary chalcocite found as rims around the bornite were probably deposited at a lower temperature at a somewhat later stage by gaseo-aqueous or hydrothermal solutions. The joint-seams referred to perhaps facilitated the passage of these solutions. Later there was slight oxidation by surface waters along the seams but the secondary chalcocite was evidently formed by solutions from below rather than by the surface waters from above.

According to the logical use of the term, secondary sulphide enrichment does not necessarily mean downward enrichment though it is usually so defined. As sulphides (and sulpho-salts) are involved and the chalcocite is secondary and as there is en-

[1] Moissan, "Traité de Chémie Minérale," Vol. 5.

richment the term *upward secondary sulphide enrichment* may be used. It is somewhat cumbersome but I know of no better term. It is perhaps well to contrast it with downward secondary sulphide enrichment.

The idea of upward secondary sulphide enrichment I gained not from any theoretical or *a priori* considerations but from the study of thin sections of the Plumas County ores to which reference has been made.

Several months after I reached the conclusion that the chalcocite in the Plumas County ores was formed by ascending solutions I ran across the following statement made by Weed[1] in an article entitled "Ore Deposition and Vein Enrichment by Ascending Hot Waters."

> "The enrichment of mineral-veins as the result of the migration of material from an upper oxidized or disintegrated part of a vein to a lower level, where it is redeposited, is now, I believe, quite generally accepted as one explanation of the occurrence of bonanzas in gold- and silver-veins, as well as that of bodies of high-grade ores in cupriferous deposits. Vogt has called attention to the fact that there are numerous examples of such rich shoots which are 'of exclusively primary character and dependent upon the laws which governed the original ore-deposition.' To this I would add that there are also other examples which are neither of primary origin nor due to descending waters, but result from a reopening of the veins and their penetration by ascending heated waters whose metallic contents are deposited by reaction with the primary pyrite (and possibly other minerals), forming 'secondary' enrichments."

Weed attributes the bonanza silver ores of Neihart, Montana, and the enargite of Butte, Montana, to secondary enrichment by ascending solutions but says nothing about chalcocite.

This paper by Weed has evidently been overlooked, even by Weed himself, for in his recent report of Butte[2] there is no mention of even the possibility of upward secondary enrichment.

The formation of chalcocite at Butte is one of the most interesting and widely discussed questions in the literature of ore-deposits, for the Butte mines are unique because of the great

[1] *Trans. Am. Inst. Min. Eng.*, Vol. 33, p. 747, 1902.
[2] Prof. Paper, U. S. Geol. Surv., No. 74, 1912.

depths at which large masses of chalcocite-bearing ores are found.

Until recently chalcocite has been generally looked upon as a product of descending sulphide enrichment. The discovery of graphic intergrowths of chalcocite and bornite in the Virgilina district of North Carolina and Virginia by Laney,[1] in 1911, amounted practically to proof of the primary origin of chalcocite. Graton and Murdoch,[2] from a careful microscopic study, come to the conclusion that chalcocite is often primary.

As to the Butte chalcocite S. F. Emmons,[3] H. V. Winchell,[4] Kirk,[5] and Weed,[6] all express the opinion that it is largely of secondary origin.

Sales[7] was the first to assign a primary origin to the deep-seated chalcocite at Butte. Graton and Murdoch[8] come to the same conclusion by a microscopic study of the ores.

Two of the more recent complete papers which take almost diametrically opposite views as to the origin of the Butte chalcocite are those of Kirk[9] and Sales.[10] The controversy concerns the gray massive or solid chalcocite mixed with bornite and enargite from the deeper levels.

All will probably admit that the "sooty" chalcocite, which occurs just below the oxidized zone, is formed by descending waters while the occurrence of large, distinct crystals[11] of chalcocite in the deepest levels may be taken as evidence of their primary origin by ascending solutions.

Kirk's[12] arguments in favor of the secondary origin of chalco-

[1] ECON. GEOL., Vol. 6, pp. 399–411.
[2] *Bull. Am. Inst. Min. Eng.*, No. 77, pp. 741–797, May, 1913.
[3] *Loc. cit.*, 1900.
[4] *Bull. Geol. Soc. Am.*, Vol. 14, pp. 269–276, 1903.
[5] ECON. GEOL., Vol. 7, pp. 35–82, 1912.
[6] Prof. Paper 74, U. S. Geol. Surv., 1912.
[7] ECON. GEOL., Vol. 5, p. 681, 1910.
[8] *Loc. cit.*, p. 768.
[9] ECON. GEOL., Vol. 7, pp. 35–82, 1912.
[10] *Bull. Trans. Am. Inst. Min. Eng.*, No. 80, pp. 1523–1626, August, 1913.
[11] I have seen pseudo-hexagonal chalcocite crystals of tabular habit from Butte which measure up to one inch in size.
[12] *Loc. cit.*

cite by descending solutions are based principally upon its association with kaolin. As Sales[1] has pointed out, this association does not prove that kaolin and chalcocite have formed from the same kind of solutions. But even if that be granted, the kaolin may have been formed by ascending waters instead of by descending waters. Collins,[2] Butler,[3] Rösler,[4] and Gregory,[5] all assign a deep-seated origin to some kaolinite. Rösler goes so far as to say that it is always a pneumatolytic product, but its occurrence in sedimentary rocks is an argument against this extreme view. Kirk[6] says that casual observers distinguish between primary and secondary chalcocite according as it is in solid or sooty form. As Kirk determined the secondary character of both forms by microscopic examination he lays no stress upon the difference between the two forms. He thinks that solid chalcocite formed when the deposition of chalcocite kept pace with the solution of pyrite and the sooty chalcocite when the solution of pyrite was more rapid than the deposition of chalcocite. This may be true, but Graton and Murdoch[7] state that the sooty chalcocite represents a stage of incipient decomposition. At any rate these two forms of chalcocite at Butte represent distinct stages of chalcocite deposition.

In a recent, very complete article on the Butte ore-deposits, Sales[8] presents evidence that the massive chalcocite is largely primary and has been formed by ascending solutions. Mr. Sales' article is probably the most complete one that has yet appeared on the Butte deposits and as he has had unusual opportunities for observation and study his conclusions deserve careful consideration.

His arguments favoring the primary origin of chalcocite are as follows:

[1] *Loc. cit.*, p. 1624.
[2] *Mineralogical Magazine*, Vol. 7, p. 205.
[3] *Ibid.*, Vol. 15, p. 128.
[4] *Neues Jahrb. f. Min.*, Beil. Bd., Vol. 15, p. 231, 1902.
[5] Econ. Geol., Vol. 5, p. 678.
[6] *Loc. cit.*, p. 73.
[7] *Loc. cit.*, p. 770.
[8] *Loc. cit.*

1. Its occurrence in abundance at deep levels.

2. Its intimate association with bornite, pyrite and enargite in a manner indicating their simultaneous deposition.

3. The occurrence of chalcocite is independent of the present surface topography.

4. Chalcocite is due to a relatively old mineralization for there are indications that massive chalcocite existed prior to the Steward fault period.

5. Chalcocite replaces granite at deep levels.

6. Certain ore-shoots are capped by hundreds of feet of barren crushed granite.

7. The occurrence of undoubted primary ores in faults of the Steward system which cut chalcocite ore-bodies in the Blue veins is proof that ascending solutions depositing primary ore continued in action after the formation of the Blue vein chalcocite.

8. The size and richness of the ore-bodies have no apparent relation to the depth of the zone of oxidation.

9. In the Mountain Chief ore-shoot of the Jessie vein an ore consisting of chalcocite, bornite, enargite, and pyrite lies below chalcopyrite ore (see plate V., p. 1557).

All of these arguments, in favor of the formation of primary chalcocite by ascending solutions, are valid. Sales' valuable paper lacks but one thing and that is the microscopic evidence of the primary character of the chalcocite. If we omit the second of the above arguments, which was apparently not based upon microscopic examination, we have proof simply that the chalcocite is formed by ascending solutions. The primary or secondary nature of the chalcocite, then, is in doubt. Simpson[1] made a microscopic study of the Butte ores but as his object was primarily to determine to what the copper content of the low-grade copper-bearing pyrite was due, he naturally avoided the high-grade chalcocite ores. He found, however, that chalcocite was the last mineral formed.

I have made polished sections of all the rich chalcocite ores from Butte that are available. The specimens consist of solid,

[1] ECON. GEOL., Vol. 3, p. 635, 1908.

massive chalcocite, with which are associated either bornite or pyrite. Unfortunately I do not know the levels or mines from which these specimens come.[1]

No. 1 is a massive chalcocite in which are embedded irregular pieces and discontinuous stringers of bornite (see Fig. 71). The secondary nature of the chalcocite is apparent.

No. 2 appears nearly homogenous in the hand specimen but the polished section shows large, irregular pieces of bornite embedded in a matrix of solid chalcocite, the chalcocite being in slight excess. There is also a little pyrite present. As the chalcocite surrounds and penetrates the bornite in veinlets it is evidently formed at the expense of the bornite.

No. 3 consists of irregular streaks of bornite and chalcocite. Although the bornite is in excess the chalcocite constitutes its matrix. The invasion of the chalcocite into the bornite is very clear.

FIG. 71.

FIG. 71. (×5.) Bornite (bo), chalcocite (cc). Butte, Montana.

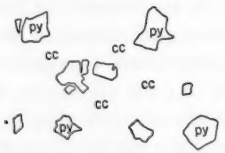


FIG. 72.

FIG. 72. (×5.) Pyrite (py) and chalcopyrite (cc). Butte, Montana.

No. 4 is a massive chalcocite with conchoidal fracture and fine granular structure somewhat resembling fine-grained galena. Polished sections show small, widely spaced, subhedral crystals of pyrite as illustrated by Fig. 72. The pyrite boundaries are somewhat irregular as if the chalcocite had been formed at its expense. It is probable that bornite was originally present in this specimen and has been entirely replaced by the chalcocite, pyrite perhaps remaining behind because it is resistant.[2]

[1] Recently I have examined a specimen from the 1600-ft. level of the Leonard mine which shows chalcocite secondary after bornite.

[2] In specimens from Bingham, Utah, the order or ease in which minerals were attacked by chalcocite is: (1) bornite, (2) chalcopyrite, (3) pyrite.

The granular character of this chalcocite is perhaps indicative of the secondary origin but the lack of it does not necessarily mean that the mineral is of primary origin. In specimen No. 1, for example, the massive chalcocite is certainly secondary but it does not show a fine-grained structure.

The microscopic evidence proves the secondary character of the massive chalcocite. I have also observed chalcocite formed at the expense of bornite in specimens from the Poderosa mine, Collahuasi, Chili, in lignite replacements from the Sierra Oscura Mts., New Mexico, and in veinlets in monzonite-porphyry from Bingham, Utah. Chalcocite secondary after bornite was also observed by Graton and Murdoch on specimens from Ajo, Arizona, and by Weed in the Virgilina district of North Carolina and Virginia.

One of Graton and Murdoch's figures (No. 22, the right-hand figure[1]) of the Butte ores I would interpret as secondary chalcocite formed from bornite instead of as a sub-graphic intergrowth of bornite and chalcocite. A sharp boundary between two minerals is not incompatible with the formation of one at the expense of the other.

Kirk argues in favor of secondary chalcocite formed by descending solutions, while Sales argues in favor of primary chalcocite formed by ascending solutions. While Weed[2] comes to the conclusion that most of the chalcocite is the product of descending sulphide enrichment he makes the following significant statement:

> ". . . It is undoubtedly in process of formation by descending waters at the present time but as the great ore-bodies are far below the present level of ground water they can not be produced by the reactions commonly offered in explanation."

The great depth of oxidation and enrichment at Bisbee (down to 1,600 ft.) has been satisfactorily explained by Ransome[3] as due to oxidation and enrichment in pre-Cretaceous time. But accord-

[1] *Loc. cit.*
[2] Prof. Paper, U. S. Geol. Surv., No. 74, p. 76, 1912.
[3] Bull. U. S. Geol. Surv. No. 529, p. 182, 1913.

ing to Sales[1] there is no necessity of assuming extremely deep meteoric ground-water circulation to account for the Butte chalcocite. The secondary character of the massive chalcocite is proved by microscopic evidence given by the writer.[2] But the arguments of Sales against the formation of chalcocite by descending solutions are, in my opinion, unanswerable. *As far as the available evidence goes, do we not have proof of the formation of massive chalcocite at Butte by upward secondary sulphide enrichment?* Only in this way can the conflicting views of competent observers be reconciled.

Then, instead of two periods of chalcocite formation we have three:[3]

1. Primary chalcocite formed by ascending solutions.
   Virgilina District, N. C.-Va.; Butte.
2. Secondary chalcocite formed by ascending solutions.
   Butte; Plumas Co., Cal.
3. Secondary chalcocite formed by descending solutions.
   Bisbee; Morenci; Butte.

All three of the stages are probably found at Butte. It must be admitted that the addition of a third stage of chalcocite deposition complicates matters, but the evidence points in that direction.

The criteria for upward secondary sulphide enrichment must be of both a geological and a mineralogical nature. Without microscopic evidence it is doubtful whether it can be distinguished from primary enrichment and without geological evidence it is doubtful whether it can be distinguished from downward secondary enrichment.

[1] *Loc. cit.*, p. 1618.

[2] Kirk (*loc. cit.*) also mentions that he has repeatedly observed solid chalcocite surrounding a nucleus of pyrite.

[3] Prof. C. F. Tolman has suggested a fourth possibility, *i. e.*, primary chalcocite formed by descending solutions.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

FIELD AND OFFICE METHODS IN THE PREPARATION OF GEOLOGIC REPORTS.

Sir: The following method of finding the line of strike and dip of an underground stratum from the depths of three wells may prove of interest to those engaged in the search for coal or in working out the lay of any underground stratum, where natural outcrops are scarce.

After the sites of the wells have been plotted to scale, and the depths found, take a compass and describe a circle around each well, with a radius (to any other convenient scale) in each case equal to the depth of the well. (See Fig. 73.) Then draw the three pairs of common tangents to the circles, and produce them until they intersect. The three points of intersection thus found will fall on a straight line, which is the line of strike required.

After the line of strike is found, the amount of the dip is a simple matter.

A professor in one of our British universities, who has attained to high distinctions in the mathematical world, and to whom I submitted this method, says, "The method shows the practical bearing of some theorems that I have always thought of as belonging to very pure mathematics." He adds, "There is a relation with Menelau's Theorem, . . . Most books on geometry give your result about three circles as a consequence of this theorem."

Another method, which perhaps is not so simple as the foregoing, but which was the means of leading me to the above result, may also be of interest.

After the well sites are plotted and the depths found, form the triangle (*ABC*), draw three parallel lines (*Aa, Bb, Cc*) in any direction through the wells, and make each respectively equal to the depth of the well through which the line is drawn.

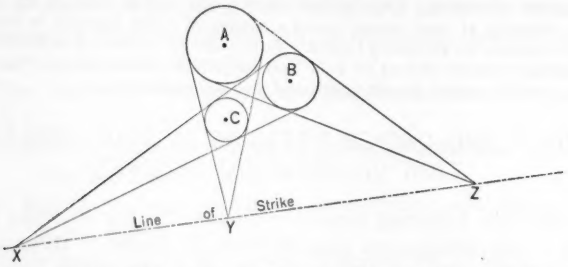


FIG. 73. First method. *A, B,* and *C* = the wells. (1) Round *A* describe a ⊙, radius = depth at *A*. (2) Round *B* describe a ⊙, radius = depth at *B*. (3) Round *C* describe a ⊙, radius = depth at *C*. (4) Draw common tangent to ⊙'s *A* and *B*, meeting in *Z*. (5) Draw common tangent to ⊙'s *A* and *B*, meeting in *Y*. (6) Draw common tangent to ⊙'s *B* and *C*, meeting in *X*. (7) *XYZ* = line of strike required.

(See Fig. 74.) A new triangle (*abc*) is thus formed. Now, in the two triangles (*ABC* and *abc*) produce the corresponding sides (*AB, ab; AC, ac;* and *BC, bc*) until they intersect, then the three intersections thus found will fall on a straight line, which is the line of strike required, and is in effect the identical line in the first method.

Writing of this method, my friend says, "There is a relation to Desargue's Theorem. . . . This, as you say, is more evident when the triangles are not in one plane than when they are."

With the first method there is only one solution, but in the second method there are four solutions, and it is interesting to note that the figures obtained are simplified if the parallel lines be drawn, either parallel to the magnetic meridian, or to one of the sides of the original triangle.

The second method I had the pleasure of showing to Dr. C. W. Hayes when in Mexico.

I have worked out proofs for my results, and long trigonometrical formulæ from which it is possible to find the angle of

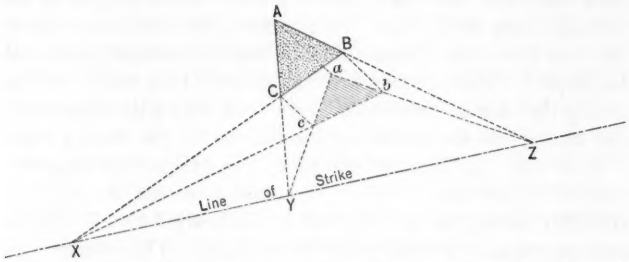


FIG. 74. Second method. *A*, *B*, and *C* = the wells. (1) Draw *Aa*, *Bb*, *Cc* parallel in any direction. (2) Make *Aa* = depth at *A* (for convenience made twice the depth of above. (3) Make *Bb* = depth at *B* (for convenience made twice the depth of above). (4) Make *Cc* = depth at *C* (for convenience made twice the depth of above). (5) Join *abc*. (6) Produce *AC* and *ac* to meet in *Y*. (7) Produce *AB* and *ab* to meet in *Z*. (8) Produce *BC* and *bc* to meet in *X*. (9) *XYZ* = line of strike required.

any side with the line of strike and the amount of the dip in terms of the sides and angles of the original triangle and the depths of the wells. These proofs are, however, too lengthy for insertion.

F. W. MOON.

HYDROTHERMAL ALTERATION.

Sir: In a recent number of ECONOMIC GEOLOGY (Vol. VII., No. 8, December, 1912), there appeared an article by E. S. Moore, entitled "Hydrothermal Alteration of Granite and the Source of Vein-Quartz at the St. Anthony Mine." Because of a marked discordance between the wall-rock alteration described, and the changes that have taken place in cases of known hydrothermal metamorphism, a somewhat careful examination of the data in the article referred to was undertaken by the writer. The results of this critical study are contained in the succeeding paragraphs.

1. In his comparison of the analyses representing different stages of alteration, Mr. Moore draws his conclusions from direct subtractions of the percentages of the various constituents, without taking into account the fact that a certain weight of an altered rock may have developed from a greater or less weight of the corresponding fresh rock. As the change in total mass can at best only be surmised, a more rational basis for comparison should be adopted. This is found in a comparison of the ratios existing among the various constituents in the fresh rock with those existing among the corresponding constituents in the altered rock. This is most readily accomplished by the straight-line diagram[1] method of platting. From an examination of the platting it is seen that during the alteration SiO_2, CaO, MgO and K_2O have been decreased in amount relatively to Al_2O_3. This change suggests weathering rather than a hydrothermal alteration. On the other hand, the marked increase in the Na_2O/K_2O ratio is in direct contrast with the tendency evident in other cases of hydrothermal action, but does not seem to agree much better with changes known to take place in weathering, where Na_2O is lost relatively to a greater extent than K_2O.

A possible explanation for this peculiar alteration is that the veins might be fillings of fissures, whose walls had been katamorphosed before the period of vein formation. In this case it would be necessary to assume a great accession of Na_2O during the period of hydrothermal metamorphism, so as to more than make up for the amount previously lost in weathering. From the nature of the case, this latter explanation does not seem plausible.

2. The mineralogical composition of the various samples calculated from the chemical analyses does not in any case check with the petrographical descriptions.

The mineralogical composition of No. 337, the fresh granite, was calculated by the writer in accordance with the list of minerals given by Mr. Moore on page 757. In this petrographical description, muscovite, apatite, sericite and limonite are noted. In the analyses of the same rock there is no determination of

[1] Mead, W. J., "Some Geologic Short-Cuts," ECON. GEOL., Vol. VII., No. 2, 1912, p. 136.

H_2O, P_2O_5, F or Cl, which are constituents of these minerals, although the analysis totals 99.63 per cent. Also, after the minerals mentioned in his description had been accounted for as well as possible in the calculation, there remained an excess of 6.18 per cent. Al_2O_3. Owing to the large amount of free quartz, this Al_2O_3 would be present as an aluminum silicate, *e. g.*, andalusite. It would require 9.78 per cent. of this mineral to account for the excess Al_2O_3. It is remarkable that a mineral constituting almost 10 per cent. of a rock should escape notice during a microscopic examination. If the petrographical description as given is correct, it would appear that there was an error in the chemical analysis. If the latter be correct, it would be difficult to explain the presence of such a mineral as andalusite except as the anamorphosed product of kaolin, or bauxite and quartz.

In the recalculation of the mineral composition of No. 335, from the chemical analysis, further difficulties are met with. The specimen is described thus:

> "It consists of a yellowish-green, almost greasy mass of scaly mica, believed to be both sericite and paragonite, impregnated with quartz stringers. . . . The loss of all evidence of feldspars, including their crystal outlines, and the recrystallization of the quartz, together with a tendency for the latter to segregate into stringers."

An attempt was made to recalculate the analysis of this sample on the basis of quartz, sericite, and paragonite as the three chief constituents. To put all the alkalies into sericite and paragonite would require 27.80 per cent. Al_2O_3, whereas the analysis only shows 20.44 per cent.—a deficiency of 7.36 per cent. This would also require 3.25 per cent. H_2O, of which none is represented in the analysis, which totals 99.47 per cent. To so adjust the alkali percentages to satisfy the Al_2O_3 for silicates would require the presence of about 20.5 per cent. of feldspars. No mention of feldspars is given in the petrographical description. In this case it is certain that an error of some importance is present in either the microscopical or chemical analysis.

Specimen No. 336, which represents an intermediate stage in the alteration, is described microscopically as follows:

"The feldspars have nearly all decomposed, only a little microcline remaining. They have almost entirely changed to sericite or paragonite, and free quartz, in some cases the outlines of the former crystals being preserved in the scaly mica. . . . Several crystals of apatite, highly fractured and surrounded by quartz and scaly mica, the latter often filling the cracks in the apatite, are seen. A stain of iron oxide along planes of weakness is common."

A mineralogical composition, calculated from the analysis on this basis, would require 4.7 per cent. more Al_2O_3 than is given, as well as 3.0 per cent. H_2O, of which no determination is recorded. P_2O_5, F or Cl would also be necessary. The analysis as given adds up to 99.44.

The discrepancies above noted seem to be of sufficient magnitude to seriously affect Mr. Moore's conclusions as to the nature of the alteration described.

W. L. Uglow.

THE FINENESS OF GOLD IN THE FAIRBANKS DISTRICT, ALASKA.[1]

Sir: The paper of Philip S. Smith, in which valuable data on the fineness of gold in the Fairbanks district, Alaska, have been brought together, has led me to a consideration of the method commonly employed in determining the extent to which gold is refined in the channels of placer streams. It is suggested that in determining the amount of this refining, one effective geologic process is generally ignored. The method usually adopted by writers on this subject is to compute the average fineness of the placer gold, and to subtract from it the average fineness of the vein gold; the difference is considered to measure the refining action that has taken place in the stream bed. This overlooks one important step, namely, the refining that goes on when denudation brings deep vein gold into the zone of oxidation. A striking example of the extent to which such refining in the zone of oxidation may take place is the well-known case of Mt. Morgan,

[1] Published with the permission of the Director of the U. S. Geological Survey.

Australia, in which the gold in the unoxidized ore has a fineness of about 570, whereas the outcrop gold to the amount of thousands of ounces assayed 998 to 999 fine.[1] As this notable increase in fineness has been effected in the outcrop, it will be seen that where placers are derived from the destruction of outcrops carrying such high-grade gold, not much work is left to be done by stream action.

A priori it is to be expected that a certain amount of refining of the gold will go on in the outcrops of the veins, since there is usually evidence of some solution and redeposition of gold in the zone of oxidation. The amount of refining that thus takes place will depend upon a number of factors, the more important of which are the chemical reagents active during oxidation and the physiographic history of the region.

It has been shown by Don,[2] by Stokes, and by Brokaw,[3] that despite long assertion to the contrary, gold is not soluble in ferric sulphate solutions. On the other hand, silver is known to be soluble in these solutions[4] and as ferric sulphate is prevalent in oxidizing gold ore-bodies, considerable refining of the gold by the solution and removal of the alloyed silver is to be expected. Further, if both metals are taken into solution by any reagents whatever, the gold, being far more easily reduced from its solutions than silver, will be deposited in a purer state than that in which it existed in the unoxidized vein.

To obtain data concerning the actual extent of this refining, however, is difficult. Don seems to be the only author who has investigated this matter quantitatively.[5] His assay results of the relative fineness of outcrop and deep vein gold show that in the samples examined by him, the amount of refining ranges

[1] Dunn, E. J., "The Mt. Morgan Gold Mine, Queensland," *Proc. Roy. Soc. Victoria*, Vol. 17, new series, Part 2, p. 351, 1905.

[2] Don, J. R., "Genesis of Certain Auriferous Lodes," Amer. Inst. Min. Eng., *Trans.*, Vol. 27, p. 598, 1897.

[3] Emmons, W. H., "The Enrichment of Sulphide Ores," U. S. Geol. Survey Bulletin 529, p. 126, 1913.

[4] Clarke, F. W., "Data of Geochemistry," U. S. Geol. Survey Bull. 491, p. 620, 1911.

[5] *Op. cit.*, pp. 607–609.

from 6 to 39 parts per thousand. According to Lindgren and Ransome[1] much of the free gold of the ordinary oxidized ore of Cripple Creek is entirely free from silver.

The conclusion from the preceding observations is that in order to obtain the amount of refining that takes place in placer streams it will be necessary to subtract the average fineness of the *outcrop* gold from the average fineness of the placer gold. The method in vogue, which ignores an important geologic process, gives results that are invariably too high. In view of these considerations it is probable that the apparent increase of fineness shown by the Tertiary gold of California as contrasted with the Pleistocene placer gold of Fairbanks, Alaska, is not due so much to the greater age of the California gold as to the fact that the average fineness of the California lode gold, 757, which was used as the basis of comparison, represents largely the average value of deep vein gold. If, for example, the average fineness, 853, of the lode gold of Calaveras Co., California, as deduced from the average of 11 mines operating in 1884,[2] is compared with the average fineness of the lode gold of 12 mines operating in 1898,[3] when it had fallen to 814, it will be seen that a far smaller amount of refining of the placer gold is indicated than was believed to have taken place by Lindgren, who used only the later figures.[4] From the earlier figures it appears that nearly one half of the refining attributed to stream action was in reality due to refining of the gold in the outcrop zone.

ADOLPH KNOPF.

[1] "Geology and Ore Deposits of Cripple Creek District," U. S. Geol. Survey, Prof. Paper No. 54, p. 204, 1906.

[2] Fourth Ann. Rept., California Min. Bur., p. 222, 1884. If one exceptionally low value is omitted, the average fineness would increase to 882.

[3] "California Mines and Minerals," San Francisco, 1899, p. 179.

[4] "Tertiary Gravels of the Sierra Nevada," U. S. Geol. Survey, Prof. Paper No. 73, p. 69, 1911.

REVIEWS

Geologische Diffusionen. By R. E. LIESEGANG. Theodor Steinkopff, Dresden and Leipzig, 1913, 180 pp., 44 text figs.

There has recently appeared under the title "Geologische Diffusionen" a small volume of 19 chapters, which is worthy of careful examination by geologists generally. The aim of this work is to make clear the rôle of diffusion in geologic processes and to interpret various geologic phenomena in terms of the laws of diffusion.

The introductory chapters deal with the phenomena and general laws of diffusion. They deal with the substances capable of diffusion, the geologic media in which diffusion can take place, the concentration and dispersal of material by diffusion, the tendency of diffusion processes to obliterate angles and corners, and the nature of endogenic and exogenic processes. The method of elucidation is largely by the description of simple illustrative experiments. This method has perhaps the disadvantage of detracting from the systematic presentation; it is somewhat disjointed and lacks the force inherent in a continuous exposition of the basic principles. The theoretical discussion strikes the reviewer as somewhat brief. Fick's law, the principle of Soret, and the relation of diffusion to osmotic pressure are not even mentioned; these omissions, when the work passes to a second edition, can easily be remedied.

Too great a stress is laid on the statement that diffusion phenomena have not received attention from geologists. As a matter of fact they have been applied to various geologic processes. To cite a single instance: Becker, as early as 1893, suggested that the wall rocks of veins act as semi-permeable membranes, and that the concentration of minerals within the veins may be a species of concentration by dialysis. Lindgren and Ransome have discussed the applicability of a modified form of this hypothesis to the ore deposits of Cripple Creek. Reid attempted to apply it to the copper deposits at Copperopolis, Cal., but it must be admitted that he did not clearly realize that diffusion is a molecular, not a molar phenomenon.

Of special interest to economic geologists is the discussion of the secondary migration of metals in ore deposits, and the defense of the lateral secretion theory, or perhaps more accurately stated, the critical discussion of the arguments leveled against that discredited theory. The experimental synthesis of a "vein" of silver chloride by "lateral secre-

tion" from a medium slightly impregnated with silver nitrate, is a highly suggestive example of an exogenic process. This process is doubtless of importance in nature, but geologists will probably not ascribe to it the transcendent rôle that the chemist does.

Liesegang has overlooked the subject of the metasomatic alteration of vein wall rocks. This is to be strongly regretted, for it offers a virgin field for the physical chemist. The ablest geologists have long occupied themselves in this field, but the results, as measured by the formulation of laws based on physical chemical principles, have so far been disappointingly small.

The phenomenon of rhythmic precipitation is elucidated in Chapter 10, and this concept is one of the most important new features of the book. By application of the principle of rhythmic precipitation plausible explanations are advanced for such diverse things as banding in agates, weathering rings, Eozoon structures, banded flints, and ore-arteries. Inasmuch as the major portion of the book is devoted to the geologic application of this principle, it is pertinent to explain it here.

The formation if insoluble precipitates usually takes place in one stage, proceeding continuously toward completion. Under certain conditions, however, the reaction may proceed rhythmically and a periodic precipitation ensue. This phenomenon, discovered by Liesegang in 1896, may be illustrated as follows: If a drop of $AgNO_3$ solution is placed on a plate that has been coated with gelatin impregnated with $K_2Cr_2O_7$, a series of concentric rings consisting of the insoluble compound $Ag_2Cr_2O_7$ will be formed; the rings become successively spaced at wider intervals apart in proportion as the distance from the center increases. This concentric system was termed Liesegang's rings by Ostwald, who also advanced the first explanation of the phenomenon. This explanation states that as the silver nitrate diffuses otuward a supersaturated solution of silver bichromate is formed; when the metastable limit of this solution becomes exceeded the silver bichromate is precipitated, forming the first ring; the continuous outward diffusion of the soluble silver salt causes a renewed formation of silver bichromate solution in the zone surrounding the first ring until precipitation again ensues, and so on. In this way a rhythmic precipitation of the insoluble silver bichromate will take place at the loci of supersaturation. This explanation has not passed unchallenged, but it has so far withstood all attacks.

The phenomenon of rhythmic precipitation has since been investigated by many others. Morse and Pierce, and others subsequently, have used tubes, instead of plates, and have obtained a series of laminæ standing at right angles to the axes of the tubes. What is important from the standpoint of geology is the fact that gelatin or other colloidal media are not essential to the production of the rings and laminæ, although the

colloidal media are favorable to the preservation of these structures. Liesegang has also discovered an interesting class of substances termed by him "form catalyzers." This name is applied to those substances whose mere presence in traces suffices to cause a rhythmic precipitation of other substances that would not normally be precipitated rhythmically. As is true of chemical catalyzers, so with the form catalyzers; they do not appear in the final product.

The recognition that certain reactions may take place rhythmically is of considerable importance to geology, for it has been universal custom to look upon banding, lamination, and crustification as conclusive proof of exogenous origin; that is, that the growth represented by these structures took place by successive increments, each of which represents a periodic fluctuation in the character of the material supplied. If the principle of rhythmic precipitation is applied to such structures a widely different interpretation of their origin becomes possible; layering is then no self-evident proof of growth by the superposition of successive increments, and a commonly accepted geologic tenet loses its supposed exiomatic character.

The earliest application of this principle to geologic phenomena was by the present reviewer in 1908 when certain banded orbicular forms produced by contact metamorphism in the Alaskan tin region were explained as probably due to rhythmic precipitation; the banding in metasomatically altered limestone adjoining stanniferous and allied veinlets was regarded as even more certainly of this origin. Independently of this, however, the subject in its geologic bearing has received considerable attention in Germany, principally by Liesegang. Remarkably successful have been the attempts to imitate the banding of agates by means of silver chromate lines. According to the common explanation agates are the steam cavities in melaphyres that have been filled with silica, and the banding is due to abrupt alternations in the character of the material supplied during growth. The banding is therefore, due to an external rhythm. The diffusion hypothesis would explain it as due to an internal rhythm. The vesicles are conceived as first filled with gelatinous silica and the banding is brought about either by (1) subsequent diffusion from the walls of the vesicles which induced rhythmic precipitation of an iron compound contained in the silica; or (2) the iron compound may diffuse into the silica where it may be precipitated rhythmically; or (3) the iron compound may pseudomorphously replace a previously rhythmically precipitated substance, as for example, calcium carbonate. Although this hypothesis does not overcome all the difficulties that are presented by the structures of agate, yet it is far more plausible than the usual geologic explanations. Even the apparent supply ducts of the agate amygdules can be perfectly imitated by means of the silver chromate lines, as is strikingly illustrated in Fig. 8.

A whole array of other geologic structures can be explained, in some instances with strong probability, as originating through rhythmic precipitation. These include the system of rings produced in rock weathering, concretions in sedimentary rocks, the Eozoon Canadense, formerly regarded as a huge Algonkian foraminifer, lemniscate-shaped concretions (marlekor), banded flints, and "ore-arteries" which are known from Pitkaranta, Finland and from Seward Peninsula, Alaska. Cross-sections of these arteries show concentric bands of magnetite alternating with bands composed of an intergrowth of fluorite and vesuvianite. The Finnish ore arteries were regarded by Trüstedt as due to crustification, *i. e.*, to centripetal growth; the Alaskan were regarded by the present reviewer as produced by rhythmic precipitation, *i. e.*, to centrifugal growth. The crucial test between these diametrically opposed explanations lies in the mathematical character of the pattern formed by the interference of contiguous arteries. These patterns are lemniscate-shaped. Such lemniscates have been perfectly reproduced by Liesegang by the interference of contiguous silver bichromate ring systems.

A chapter is given to a discussion of the origin of gold ore deposits. Special reference is made to the work of Hatschek and Simon whose work on the reduction of gold in silicic-acid gels is regarded as of high importance to geochemistry. The Witwatersrand deposits are also interpreted in terms of the diffusion theory. In these things it would seem, however, that the speculations of the chemist have not been held in restraint by the field knowledge of the geologist.

The author states that he realizes that rhythmic precipitation is not to be regarded as a panacea for all difficulties. Although he has occasionally gone too far in his application of this principle, it is nevertheless highly probable that many more geologic phenomena, in addition to those discussed in the volume under review, may more reasonably be explained when rhythmic precipitation is considered as a genetic factor. As an addition to the scant literature of physical chemistry applied to the problems of geology this book is to be strongly commended.

ADOLPH KNOPF.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

SIDNEY PAIGE AND E. RUSSELL LLOYD.

METALLIFEROUS DEPOSITS.

COPPER.

Einige Untersuchungen der kupferkiesführenden Mineralgänge am Monte Mulatto bei Predazzo. Von M. LAZAREVIC und E. KITTL. Oesterreichische Zeitschrift für Berg- und Hüttenwesen, July 26 and Aug. 2, 1913, pp. 407–413, 421–430, Vol. LXI.

Das Kupferbergwerk zu Kedabeg, Government Elizabethpol Kaukasus, Russland. Chaustoff., Zeit. f. prakt. Geol., July, 1913.

The copper mine at Kedabeg, administrative district of Yelizavetpol, Caucasus.

Some Manganese and Copper Developments in the Olympic Mountains, Washington. Pac. Min. Journ., July, 1913.

Chalcocite Deposition. By A. C. SPENCER. Journal of the Washington Academy of Sciences, Feb. 4, 1913, Vol. III., No. 3.

The Magistral District, Jalisco, Mexico. By EZEQUIEL ORDONEZ. Eng. and Min. Journ., Sept. 13, 1913.

Ore Deposits at Butte, Montana. By RENO H. SALES. Bulletin Am. Inst. Min. Eng., Aug., 1913, 104 pages, illustrated.

Geology of the Woody Copper District, California. By WM. H. STORMS. Eng. and Min. Journ., Oct. 4, 1913.

Formation and Growth of Disseminated Copper Deposits. By JAS. O. CLIFFORD. Mines and Methods, June, 1913.

The Mount Lyell Copper District of Tasmania. By CHESTER G. GILBERT and Jos. E. POGUE. Proc. U. S. Nat. Museum, Vol. 45, July 22, 1913, 21 pages.

Sandstone Copper Deposits at Bent, New Mexico. By SYDNEY H. BALL. Min. and Sci. Press, July 26, 1913.

The Copper Mines of the Sierra Magistral. By R. B. BRINSMADE. Mex. Min. Journ., Aug., 1913.

The Precipitation of Copper from the Mine Waters of the Butte District. By J. C. FEBLES. Bulletin Am. Inst. Min. Eng., July, 1913. 17 pages.

The Copper Mine Country. By J. B. TYRRELL. Trans. Canadian Inst. Review of published statements about Copper on Arctic Coast of North America. Concludes that existence of copper-bearing area is certain.

Relation of Outcrops to Ore at Cananea. By MORRIS J. ELSING. Eng. and Min. Journ., Feb. 15, 1913, pp. 357–362.

An analysis of the relationships of various gossans to the underlying ore bodies, at Cananea in particular. It is shown that it is very difficult to predict with certainty the value of ore beneath any particular gossan. The importance of classification of gossans with regard to their possibilities in ore, based on actual occurrences, is emphasized.

Memoire sur les Mines de Pyrite de la region de Huelva. Par M. FREDERIC GOÜIN. (suite et fin) Mines Bulletin et Comptes Rendus Mensuels de la Societe de l'Industrie Minerale. Bulletin 5^{me} serie, tome II., 12^{me} livraison de 1912, pp. 581–642.

GOLD AND SILVER.

The Rand Banket. By C. B. HORWOOD. Min. and Sci. Press, Vol. 107, Nos. 15, 16, 17 and 18.

A series of articles constituting a comprehensive treatise on the great ore deposits of the Witwatersrand in South Africa.

Ore Deposits of the Helena Mining Region, Montana. By ADOLPH KNOPF. Bulletin 527, U. S. Geol. Survey, 1912, 143 pages, 7 pls.

The Tellurides of Kalgoorlie. By J. ALLAN THOMSON. Monthly Journal of the Chamber of Mines of Western Australia, Sept. 30, 1912, 12 pages.

Geology of the Kalgoorlie Goldfield. By MALCOLM MACLAREN and J. ALLAN THOMSON. Min. and Sci. Press, July 12, 19, Aug. 2, 9 and Sept. 6, 1913, 22 pages, illustrated.

Gold Deposits of Porcupine District, Ont. By REGINALD E. HORE. ECONOMIC GEOLOGY, Aug., 1913, 7 pages.

Kirkland Lake Gold Deposits. By REGINALD E. HORE. Can. Min. Journ., July 15, 1913.

The Witwatersrand—The City Deep. By ROWLAND GASCOYNE. Can. Min. Journ., May 15, 1913, 4 pages, illustrated.

The Kennedy Mining District, Nevada. By PAUL KLOPSTOCK. Bulletin Am. Inst. Min. Eng., June, 1913, 6 pages.

The Mother Lode of California. By J. H. G. WOLF. Min. and Sci. Press, June 21 and 28, 1913, 8 pages, illustrated.

The Great Mines of Africa, XII, Van Ryn. By OWEN LETCHER. Min. and Eng. Wld., June 21, 1913.

Le District Aurifère de Porcupine, Province d'Ontario. By E. DULIEUX. Bulletin Soc. de l'Ind. Minerale, Aug., 1913, 34 pages, illustrated.

The Platoro District, Colorado. By CARL A. ALLEN. Eng. and Min. Journ., Sept. 27, 1913.

Lode Mining in the Willow Creek District. By SUMNER S. SMITH. Min. and Sci. Press, Aug. 20, 1913.

Relation of Faulting and Mineralization in Goldfield. By CORRIN BARNES and E. A. BYLER. Min. and Sci. Press, July 12, 1913.

The Yentna District, Alaska. By STEPHEN R. CAPPS. U. S. Geol. Survey Bull., No. 534, 1913, 79 pages.

Some Characteristics of the Gold-bearing Veins of Nova Scotia. By E. PERCY BROWN. Can. Min. Journ., June 1, 1913.

Geology of Rochester, Nev. By J. CLAUDE JONES. Min. and Sci. Press, May 17, 1913.

Zur Frage der Entstehung der Erzlagerstätten von Leadville (Kolorado). By L. ROSE. Glückauf, June 7, 1913, 5 pages, illustrated.
Concerning the genesis of the ore deposits of Leadville, Colorado.

Geology of Santa Eulalia, Chihuahua. By ARTHUR C. BENNER. Min. and Sci. Press, June 14, 1913.
From Report of Buena Tierra Mining Co.

Influence of Flat Dike on Ore Formations, with Reference to Cripple Creek District. By E. A. COLBURN, Jr. Eng. and Min. Journ., Sept. 27, 1913.

Origin of Lead, Zinc, and Silver in the Coeur d'Alene. By OSCAR H. HERSHEY. Min. and Sci. Press, Sept. 27 and Oct. 4, 1913.

Precipitation of Gold in Ore Bodies. Min. and Sci. Press, Aug. 23, 1913.

The Precipitation of Gold by Manganous Salts. By A. D. BROKAW. Journ. Ind. and Eng. Chem., July, 1913.

The Association of Gold Deposits with Acid Igneous Rocks in Southern Rhodesia. By H. B. MAUFE. So. Rhodesia Geol. Survey, Bulletin No. 2, 1913, 10 pages.

The Gold Placers of Antioguia, Republic of Colombia, South America. By M. H. de Hora. Bulletin Am. Inst. Min. Eng., July, 1913.

Nechi River Placer Mining, Colombia. By WM. F. WARD. Eng. and Min. Journ., Aug. 16, 1913.

The Black Sand Beaches of the South Island of New Zealand. By G. W. EATON. Aust. Min. Stand., July 3, 1913.

Ingenious Placer Operations near Manhattan, Nev. Min. and Eng. World, Aug. 2, 1913.

Placer Mining on the Cauca River in Colombia, S. A. By WM. F. WARD. Mex. Mining Journ., Aug., 1913, 3¼ pages, illustrated.

The Fineness of Gold in the Fairbanks District, Alaska. By PHILIP S. SMITH. ECONOMIC GEOLOGY, Aug., 1913, 6 pages.

The Wasp No. 2 Mine and Mill. By LEROY A. PALMER. Salt Lake Min. Rev., June 15, 1913.

The Rand's Ore Reserves. By A. COOPER KEY. Eng. and Min. Journ., July 26, 1913.

The Gold of the Klondike. By J. B. TYRRELL. Trans., Royal Soc. of Can., Vol. VI, 1912, 31 pages, illustrated. Also Can. Min. Journ., May, 1913, 7 pages.

The Coeur d'Alene Mining District. By F. R. INGALSBE, Eng. and Min. Journ., July 26, 1913.

Gold Production in Relation to Humanity: A Study of the Question: Has Gold Depreciated in Value? By EUSTACE M. WESTON. Jour. Chem. Met. and Min. Soc. of So. Africa, June, 1913.

The Gravels of Cuzco, Peru. By HERBERT E. GREGORY. Am. Journ. of Sci., July, 1913, 18 pages, illustrated.

The Gold-Copper Ore Deposits of the Guanaco, Chile. Min. Journ., July 26, 1913. From Zeit. f. prakt. Geol., July, 1913.

Grundwasserstudien. Von KEILHACK. Zeit. f. prakt. Geol., Aug., 1913. 11 pages. Illustrated.
Ground water studies.

Northern Spain as a Dredging Field. By H. L. LEWIS. Min. Journ., Mar. 29, 1913.

Notes on the Urique District. By G. I. DINWIDDIE. Mex. Min. Journ., Apr., 1913.

The Elk City Mining District, Idaho County, Idaho. By ARTHUR L. FLAGG. Bull. Am. Inst. Min. Eng., Apr., 1913, 10 pages, illustrated.

Buffalo Hump Mining District, Idaho. By ARTHUR L. FLAGG. Min. and Eng. Wld., Apr. 26, 1913.

Gold Placer Mining in Dutch Guiana. By J. B. PERCIVAL. Min. and Sci. Press, May 10, 1913.

Sudbury, Cobalt, and Porcupine Geology. By WILLET G. MILLER and CYRIL W. KNIGHT. Eng. and Min. Journ., June 7, 1913.

Contributions to the Geology and Ore Deposits of Kalgoorlie. By E. S. SIMPSON and C. G. GIBSON. Bulletin 42, West Australia Geol. Survey, Perth, 1912. 198 pages, with 3 maps, 29 plates and 2 figures.

The Secondary Enrichment of Silver Ores. By H. C. COOKE. Journ. of Geol., Vol. XXI., No. 1, 1913, pp. 1–29.

Sets forth the results of an experimental chemical investigation of the effect of certain solutions on certain silver-bearing minerals and points out the geological significance involved.

The Law of the Pay-streak in Placer Deposits. By J. B. TYRRELL. Trans. Inst. of Mining and Metallurgy, London, 1912, Vol. XXI., pp. 593–613.

A physiographic discusson of the development of stream valleys in their relation to the pay-streak. Discussion of the paper tends to limit the application of Mr. Tyrrell's hypothesis.

The Domes of Nova Scotia. By T. A. RICKARD. Trans. Inst. Min. and Metallurgy, London, 1912, Vol. XXI., pp. 506–566, with discussion.

A discussion of the structural features of these interesting quartz lodes.

The Bonnifield Region, Alaska. By S. R. CAPPS. Bulletin No. 501, U. S. Geological Survey.

An account of the geology and mineral resources (placer gold and lignite) based upon a 100-day field season during which 3100 square miles were mapped on a reconnaissance scale.

The Eagle River Region, Southeastern Alaska. By ADOLPH KNOPF. Bulletin No. 502, U. S. Geological Survey, 6 pages, maps, 1912.

A description of the geology and economic resources of the region. Gold-bearing quartz veins and stringer lodes are the important carriers of ore. An excellent example of a schistose contact zone is mapped and described. The albitization of the vein wall rocks is of special interest.

Gold and Platinum Alluvial Deposits in Russia. By LEON PERRETT. Trans. Inst. of Mining and Metallurgy, London, 1912, Vol. XXI., pp. 647-690, with discussion.

A discussion of the occurrence, prospecting and winning of platinum in Russia.

Gold Placers in Central China. By E. C. THURSTON. Eng. and Min. Journ., No. 7, pp. 270–273, 1913, illustrated.

Describes certain low grade placers in Hupeh and Hunan provinces, and the primitive methods of exploitation.

IRON.

Le Minerai de Fer dans le Monde. Ann. des Mines de Belgique, Vol. XVIII., part 3, 19 pages, illustrated.

Magnetic Iron Sands of Natashkwan, County of Saguenay, Province of Quebec. By GEO. C. MACKENZIE. Can. Dept. of Mines, 1912, 57 pages, illustrated.

Beitrag zur Kenntniss der "Itabirit" Eisenerze in Minas Geraes (Brasilien). Von GUTHMANN. Zeit. f. prakt. Geol., May, 1913, 6½ pages, illustrated.

Contributions to the knowledge of the itabirite iron ores of Minas Geraes.

Die Eisenerzlager und die Eisenindustrie von Bilbao. Dann. Stahl u. Eisen, July 17 and 24, 1913, 8½ pages, illustrated.

The iron-ore deposits and the iron industry of Bilbao.

Ueber die Amberger Erzformation. Von ROTHPELZ. Zeit. f. prakt. Geol. June, 1913, 12 pages, illustrated.

On the Amberg Ore formation. Refers to iron ore deposits.

Iron Deposits of Oyon. By LOUIS A. DELGADO. Peru Today, Mar., 1913.

Ein Titaneisenerzvorkommen kontactmetamorpher Entstehung. Von SINGEWALT. Zeit. f. prakt. Geol., June, 1913.

An occurrence of titanic iron ore of contact metamorphic origin.

El Fierro en Chile. Nuevos Reconocimientos de Algunos de los Principales Yacimientos de Minerales de Fierro de Chile. By CARLOS VATTIER. Bol. Soc. Nac. de Mineria, Mar.–Apr., 1913.

Note supplementaire sur les gisements de fer de l'Espagne. Par RAMON ADON DE YARZA. Compte Rendu de XI:e. Congress Geologique International.

Iron Making in Alabama. By WM. BATTLE PHILLIPS. Geological Survey of Alabama, 245 pages.

Iron Deposits in the Tuckahoe District, East Tennessee. By C. H. GORDON and R. P. JARVIS. The Resources of Tenn., State Geol. Survey, Vol. 2, No. 12, 1912, pp. 458–478.

Brown hematite by the decomposition and accumulation of the fer-

ruginous matter in the limestone member of the Tellico sandstone of Silurian age.

Similar in occurrence, chemical composition and physical character to the Clinton ores, but the concentration of iron due to the action of surface agencies in leaching the more soluble lime carbonate of the iron-bearing limestone and converting the primary iron carbonate into iron oxide has not progressed to any great depth. The unaltered iron carbonate rock will run from 10 to 16 per cent. iron. Are placed in the reserve, rather than the commercial class.

Studies on the Geology of the Iron Ores of Lappland. Per GEIGER. Geologiska Foreningens, I; Stockholm Förhandlingar, Geol. Fören. Forhandl., Band. 34, Häfte 7, pp. 727–789.

The author concludes that the ores are of magmatic origin and that they belong to a late stage in the magma differentiation, being rather pegmatitic than basic segregations.

Die Eisenerzversorgung Europas. Von THEODOR SEHMER. Keil, 1911, 48 pages.

Iron Ore Deposits of the Eagle Mountains, California. By EDMUND CECIL HARDER. Bulletin No. 503, U. S. Geol. Survey, 1912, 79 pages, 12 plates, 4 figures.

LEAD AND ZINC.

Development of the Wisconsin Zinc Field. By H. B. PULSIFER. Min. and Eng. Wld., June 21, 28, July 5, 12, 19, and 27, 1913. 14 pages. Illustrated.

Minerals of the Tres Hermanas District. By W. ROGERS WADE. Eng. and Min. Journ., Sept. 27, 1913.

Origin of Lead, Zinc and Silver in the Coeur d'Alene. By OSCAR H. HERSHEY. Min. and Sci. Press, Sept. 27, and Oct. 4, 1913.

Die Blei- und Zinkerzlagerstätten Aachens. Von KLOCKMANN. Metall u. Erz., Aug. 30, 1913.

The lead and zinc ore deposits of the Aix-la-Chappelle.

Ein Uranmineralien fuhren der Gang der Barytischen Bleierzformation im Weiler und Gereuth unweit der Ruine Geroldseck bei Reichenbach, Amt. Lahr. Von HENGLEIN. Zeit. f. prakt. Geol., June, 1913, 7 pages. Illustrated.

A lode of the barytic lead-ore formation carrying uranium minerals near Reichenbach Lahr District.

Occurrence of Oxidized Zinc Ores at Tintic. By EDW. R. ZALINSKI. Eng. and Min. Journ., June 21, 1913.

MERCURY, PLATINUM AND PYRITE.

The Occurrence, Distribution and Uses of Mercury. Bull. Imp. Inst., July–Sept., 1913, 17 pages.

The Occurrence of Platinum in the Urals. By E. DE HAUTPICK. Min. Journ., Sept. 20, 1913.

Beiträge sur Kenntniss der Huelvane Kieslagerstätten. Von WETZIG. Zeit. f. prakt. Geol., May, 1913, 6 pages, illustrated.

Contributions to the knowledge of pyrite deposits in Huelva.

Vorläufiger Beitrag zur Frage der Entstehung der Pyritlagerstätten in der Provinz Huelva Sud-Spanien. Von SCOTTI. Zeit. f. prakt. Geol., June, 1913.

Preliminary contributions to the problem of genesis of the pyrite deposits of Huelva Province, South of Spain.

Pyrites in Canada, its Occurrence, Exportation, Dressing and Uses. By A. W. G. WILSON. Department of Mines, Ottawa, 1912, 202 pages, 1 map, 27 plates, 29 figures.

RARE MINERALS.

Our Radium Resources. By CHARLES L. PARSONS. Address to the 16th Annual Convention of the American Mining Congress, Philadelphia, Oct. 20–24, 1913. Science, N. S., Vol. XXXVIII., No. 983, p. 612.

Some Occurrences of Wolframite Lodes and Deposits in the Tavoy District of Lower Burma. By A. W. G. BLEECK.

Sebacates and Cacodylates of the Rare Earths. By C. F. WHITTEMORE and C. JAMES. Journ. Am. Chem. Soc., Feb., 1913.

Radioactivity of the Mineral Springs of Manitou, Colo. By JOHN C. SHEDD. Proc. Colo. Sci. Soc., June, 1913, 30 pages, illustrated.

The Radio-Active Elements. By C. H. VIOL. Radium, June, 1913.

Pitchblende from Quartz Hill, Gilpin County, Colorado. By FORBES RICKARD. Min. and Sci. Press, June 7, 1913.

Zur Kenntniss des Osmiums. Von GUTBIER. Chem.-Ztg., July 17, 1913.

Relating to the knowledge of osmium.

Estudio de Algunos Minerales Raros del Estado de Chihuahua. ERNESTO WITTICH. Bol. Soc. Geol. Mex., Vol. 8, part 1, 1912.

Notes on the Occurrence of Some of the Rarer Metals in Blister Copper. By A. EILERS. Bull. Am. Inst. Min. Eng., June, 1913.

Les Metaux Speciaux—Manganese, Chrome, Silicium, Tungstene, Molybdene, Vanadium, et leurs Composes Metallergique Industriels. Par JEAN ESCARD. Paris, H. Dunod et E. Penat, 1909.

Les Petits Metaux, Titane, Tungstene, Molybdene. By P. TRUCHOT. This volume is one publication of the Encyclopedie Scientifique des Aide—Memoire; L. Isler, Secretaire general, Boulevard de Courcelles, Paris.

The Distribution of Radio-Active Substances in the Universe. By W. W. STRONG. Radium, July, 1913.

Tungsten in Boulder County, Colo. By LEROY A. PALMER. Eng. and Min. Journ., July 19, 1913, 7 pages, illustrated.

The Mineralogy of the Rarer Metals, a Handbook for Prospectors. By EDW. COHEN and WM. ORD WOTTON. Chas. Griffin & Co., Ltd., London.

From the Foreword by F. W. Harbord: "Although much has been written about the "Rarer Elements" apart from Dana, most of the reliable information is very scattered, and a handy pocketbook giving particulars of their mineralogy, mode of occurrence, rapid methods of assay and chief industrial applications should be of special interest to prospector, the mineralogist, and those engaged in the industries where the rarer metals are employed."

Tungsten and the Scheelite Mines in Nova Scotia. By VICTOR G. HILLS. Journal of the Mining Soc. of Nova Scotia, Vol. XVII., pages 55–61, 1912–1913.

Veins of quartz, ankerite, scheelite and arsenopyrite—a little pyrite and calcite—cutting folded sedimentary strata. Author believes veins were formed during metamorphism.

Rare Metal Mining in Queensland. By LIONEL C. BALL. Queensland Govt. Journ., Jan., 1913, pp. 4–7.

A résumé of recent field studies. Deposits are located either directly on or adjacent to the periphery of areas of intrusive granite. The tungsten and molybdenum minerals are believed to be magmatic differentiates of the granite.

Rare Minerals at Broken Hill, Rhodesia. By GEO. D. HUBBARD. Eng. and Min. Journ., June 28, 1913.

TIN.

Geology of the Tin Fields,—Principal Features of the Waterberg System. So. African Min. Journ., Mar. 8, 1913.

Wolfram Mines of Mount Carbine. By LIONEL C. BALL. Queensland Govt. Journ., Mar. and Apr., 1913, 12½ pages, illustrated.

Uranium in Colorado. By O. BRILL. Radium, April, 1913.

Die Vanadinerze und Ihre Aufarbeitung Manz. Metall u. Erz., Apr., 1913.

Vanadium ores and their utilization.

Cassiterite in Soil. By GILMOUR E. BROWN. Min. Mag., May, 1913.

Dredging for Tin in the Malay States. ALEXANDER COLLEDGE. Min. Mag., July, 1913.

Description of dredge at North Tambun Mine, Perak.

The Prosperity of the Federated Malay States. Editorial. Min. Journ., June 14, 1913.

The Geology of the Country around Warmbaths and Nylstroom, including the Roviberg Tin Field. By H. KYNASTON and E. T. MELLOR. Geol. Survey—Union of South Africa. Pretoria, 1912.

Tin occurs at and near granite contacts.

Tin and Topaz in New Brunswick. By R. W. BROCK. Journal of the Mining Soc. of Nova Scotia, Vol. XVII., pp. 50, 54.

Cassiterite and topaz were found in greissen (muscovite and quartz) veins associated with brown mica, feldspar, fluorite, wolframite, molybdenite, pyrrhotite, and chalcopyrite at the contact of a granite batholite with Cambro-Silurian schists. (Contact metamorphism, from argillites.)

Tin Deposits of the World. By SYDNEY FAWNS. 3d ed., 306 pp., 89 figs.

Describes general geology and methods of mining and extraction.

Around the Tasmanian Mines—The Northeastern Tin Fields. By PETER G. TAIT. Min. and Eng. Review, July 5, 1913.

Tin Mining in Mexico. By GEO. C. MASTER. Min. Mag., Sept., 1913.

Australian Tin Fields. Min. Journ., Aug. 30, 1913.

SCIENTIFIC NOTES AND NEWS

A UNIQUE FEATURE of the field work by parties of the Fuel Section of the U. S. Geological Survey during the past season was the equipment of most of the parties with apparatus for partial analytical work. This was considered advisable on account of the necessity for having accurate knowledge of the ash content of the various coal beds for the purpose of classification. In connection with the examination of bituminous shales in the Eocene beds in the region north of Grand river in Utah and Colorado, by E. G. Woodruff, the party was equipped with distillation apparatus and numerous tests were made in the field.

DR. E. T. WHERRY has resigned from the department of geology, Lehigh University, to become assistant curator of mineralogy and petrology in the U. S. National Museum.

A. A. HASSAN is studying the rock formation at the mouth of the Grand Canyon of the Colorado River, Mohave County, Arizona. He is also examining the supposed placer gold deposits found along the Colorado River.

DR. AUBREY STRAHAN has been appointed director of the British Geological Survey and Museum in succession to Dr. J. J. H. Teall, who retires on January 5, 1914.

AMONG THE RECENT PUBLICATIONS of the U. S. Bureau of Mines are the following: Technical Paper 41, "The mining and treatment of lead and zinc ores in the Joplin District, Mo.," a preliminary report by C. A. Wright; Technical Paper 51, "Possible causes of the decline of oil wells, and suggested methods of prolonging yield," by L. G. Huntley; Technical Paper 60, "The approximate melting points of some commercial copper alloys," by H. W. Gillett and A. B. Norton.

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

INDEX TO VOLUME VIII.

[NOTE.—In this index the titles of principal papers and the headings of departments, as *Discussion*, are in italics.]

Acid solutions, experiments with, 423
Acidity of waters of copper mines, 646
Actinolite, 22
Agricola, Georgius, review of work by, 509
Adamellites, 552
Adams, G. I., on occurrence of alunite, 755
Adinole, 599
Adirondacks, titaniferous magnetites, 611
Alabama natural gas fields, 525
Alabandite, 417, 419, 427; experiment in precipitating gold with, 156; experiment in precipitating silver with, 144
Albite, 22
Algæ, growing in stream of hot water, 237
Algonkian vs. Pre-Cambrian, 508
Alidade, 274
Alkaline extracts of metallic sulphides, behavior of cold acid sulphate solutions of copper, silver, and gold with (Grout), 407
Alkaline mine waters, 425
Alkaline solutions, experiments with, 427; of sulphides, 424
Allegheny formation, 520
Allen, E. T., on mineral sulphides of iron, 460, 633
Almaden silver mine, Gilpin Co., Colo., 52
Alpha mine, Ely district, Nevada, 649
Alta lode, Montana, 111
Alta mine, Helena region, Montana, 113
Alteration, hydrothermal, 797; in quartz monzonite, Rimini, 117; of covellite to chalcocite, 640
Alumina in igneous masses, 600; in magmatic emanations, 505
Aluminum, in water, 663
Alunite, composition, 762; formula, 754; in granite porphyry, 752; microscopic character, 762; occurrence, 755; origin, 764; prospecting for, 766; qualities, 760, 761
Alunite in Patagonia, Arizona, and Bovard, Nevada (Schrader), 752
Alunite deposition, time and conditions of, 765
Alunitization, zone of, at Patagonia, Ariz., 753
American Fork district, Utah, plumbojarosite, 315
Amherst quarries, Ohio, 475, 478
Analyses (*see* chemical analyses)
Andesite, Palisade, Nev., 252; analysis, 252
Andradite, 22, 599, 600
Andrews, E. B., on anticlinal theory, 542
Aneroid, measurement of horizontal distances by, 732; use in surveying, 698
Angle errors, 738
Anglesite, 10, 321
Anticlinal bulges, 535
Anticlinal structure, 529
Anticlinal theory, 541
Apatite, 22, 262
Aplite, 108
Apparatus, to show electromotive action, 571; used in synthesis of pyrite, 462
Apparent dip, tables showing, 402
Arbuckle Mountains, uplift of, 770
Areas of gas fields by states, 517
Argentite, 416, 419
Arkansas natural gas fields, 525
Armas, M., on tourmaline in Bolivian ores, 118
Armstrong, H. E., and Worley, F. P., on the hydrolytic process, 168
Arnold, R., and Anderson, R., on gas fields of California, 530
Arsenic, in water, 662
Arsenopyrite, 325, 417, 427; experiment in precipitating gold with, 156; experiment in precipitating silver with, 146
Artificial vein-formation in the Tomboy mill, Telluride, Colorado (Kemp), 543
Asphalt, in Oklahoma, 777; literature on, 303

Assays—gold of Shinarump clay at Paria, Utah, 446; ore from Wagon Wheel Gap, Colo., 243; silver ore, 52
Aubrey limestone, 438, 443
Augite, 330
Austin, W. L., on silicate zones, 35
Auxiliary point method of topographic survey, 742
Axinite, 22, 325

Bagg, R. M., *The discovery of pyrrhotite in Wisconsin, with a discussion of its probable origin by magmatic differentiation*, 369
Ball, L. C., discussion by, 382
Balltown sand (natural gas), 521
Bard, D. C., on absence of copper-sulphide enrichment in calcite, 648
Barite, 51, 241
Barnhardtite, 639
Barograph, 699
Barrell, Joseph, discussion by, 691; on contact metamorphism, 24, 45; on Marysville mining district, 23, 46; on measuring components of rocks, 123; on rocks of Elkhorn, 107; on microscopical petrography of the Elkhorn mining district, 120; on secondary silicates in Marysville deposits, 501
Barth iron ore deposit (Jones), 247
Bartlesville pool, 774
Base expansion, methods of, 740
Base line, locating and measuring, 186
Base lines, 733
Base maps, 282
Bastin, E. S., *Metasomatism in downward sulphide enrichment*, 51; on metasomatism, 643
Bastin, E. S., and Palmer, Chase, *Metallic minerals as precipitants of silver and gold*, 140
Batholith, mode of progression upward, 223
Batson sketching case, 382, 579
Bayard sand (natural gas), 521
Beaver Co., Utah, corkite, 318; plumbojarosite from, 312, 315
Beaverite, 316; analysis, 317
Beck, R., on minerals in copper shales, 164; review of paper by, 298
Becker, C. F., on alkaline solutions, 425
Becker, G. F., on age of the earth, 631; on deposition of metals, 669; on quicksilver deposits, 245; on the Comstock Lode, 245
Becquerel, A. C., on deposition of copper in a capillary, 577
Bedford shale, 475, 478, 681
Bedford-Berea unconformity, 478
Bell, J. M., and Cameron, F. K., on alkaline ground water, 623
Bell, J. M., and Fraser, Colin, review of work by, 722
Bennett, H. T., analyses by, 370
Benoist sand (natural gas), 524
Berea sand (natural gas), 521
Berea sandstone, 478; analysis of, 471; texture and qualities, 470
Berea sandstone formation of northern Ohio, Economic geology of (Burroughs), 469
Berkey, C. P., discussion by, 700
Berthelot, M., on origin of natural gas, 540
Bendantite, 318
Big Injun sand (natural gas), 521
Big Seven mine, Neihart, Mont., ore, polished section, 59
Bingham, Utah, analyses of fresh and altered limestones from, 218
Biotite, 22
Bisbee, Ariz., analyses of fresh and altered limestones from, 220; contact metamorphism, 31; ratios in unaltered and metamorphosed limestones, 503
Bischof, G., on apatite crystals, 262
Bismuth, literature on, 193
Black Jack, 417, 427
Black Warrior mine, Washington Co., Utah, minerals of, 319
Blackwelder, Eliot, discussion by, 489
Blaine formation, 772
Blake, W. P., on copper ore and garnet, 45
Blasdale, W. C., analysis by, 445
Bohnenberger solution of the three-point problem, 185
"Boiling spring," Wagon Wheel Gap, Colo., 237
Bornite, 417, 427; experiment in precipitating gold with, 156; experiment in precipitating silver with, 146; reactions with, 625
Boron, in water, 662
Boulder batholith, Montana, 105, 107, 323; mining districts bordering, 106
Boulder County, Colorado, precious metal veins, 51
Boulder Hot Springs, Montana, hot waters of, 245
Boulder sand (natural gas), 521
Boundary tracing methods, 90

Boutwell, J. M., on alteration of galena to cerusite, 321; on ores of Bingham district, Utah, 165
Bovard, Nevada, Alunite in (Schrader), 752
Bovard, Nevada, location, 757; mineralogy, 758
Bownocker, J. A., on oil and gas at Bremen, Ohio, 681
Bradford sand (natural gas), 521
Braun, F., on electrocapillary reactions, 577
Bridgeport sand (natural gas), 524
Broad-Top coalfield, 496
Brögger, W. C., on classification of rocks, 552; on contact zones, 599
Brochanthite, 321
Brock, R. W., on Boundary Creek district, 45
Brokaw, A. D., on solution of gold, 408
Broken base method of base expansion, 742
Brooks porphyry mine, composition of water from, 644
Brun, Paul, on magmatic waters, 598
Brunton, Stopford, *Some notes on titaniferous magnetite*, 670
Brunton compass, 377; attachment, 491
Buehler, H. A., and Gottschalk, V. H., on electrolytic action, 61; on oxidation of sulphides, 408, 632
Building stone, literature on, 196
Burk Burnett oil pool, Texas, 777
Burroughs, W. G., *Economic geology of the Berea sandstone formation of northern Ohio*, 469; on the Bedford-Berea unconformity, 478
Burrows, A. G., on geology of Porcupine district, 485
Butler, B. S., *Occurrence of complex and little known sulphates and sulpharsenates as ore minerals in Utah*, 311
Butler, B. S., and Gale, H. S., on occurrence of alunite, 755
Butler, B. S., and Schaller, W. T., on plumbojarosite, 312
Butler, F. H., on origin of kaolinite, 790
Butler, G. M., *Some recent developments at Leadville; the oxidized zinc ores*, 1
Butler gas sand, 521
Butte, Mont., silver in copper veins, 161; upward secondary sulphide enrichment at, 788
Byerson [Byasson, H.], on origin of natural gas, 540
Calamine, 6
Caddo gas field, Louisiana, 525, 534
Caddo oil fields, Louisiana, 532
Cadmium, literature on, 302
Caetani, Gelasio, incrustation furnished by, 543
Calcite, 22, 51; residuary, 48; rôle in chalcocite deposition, 648
Calcite-quartz-manganese veins, 500
Calcium, in water, 663
Calcium carbonate, dissociation of, 224
Caledonia mine, Cœur d'Alene district, Idaho, Secondary enrichment in (Shannon), 565
California natural gas fields, 526
California quartz mines, fineness of gold from, 454
Calkins, F. C., discussion by, 373
Cameron, F. K., and Bell, J. M., on alkaline ground water, 623
Cameron, F. K., and McCaughey, J. W., on apatite, 262
Campbell, M. R., on accumulation of natural gas, 542; on profile traverse method, 713; review by, 97
Campbell, W., on polishing sections, 673; on titaniferous magnetites, 671
Cap quartz, 298
Capel, from Dolcoath mine, Cornwall, 112
Carbonaceous deposit, A remarkable, near Putnam, New Mexico (Foster), 360
Card indexing notes, 395
Carey act, 347
Caribou silver veins, Colorado, 52
Cartographic unit in mapping, determination of, 82
Catskill formation, 521
Cavalieri's theorem, 126
Cerusite, 321
Chalcocite, 417, 427, 789; as precipitant of silver and gold, 140; efficiency in precipitating silver, 145; experiment in precipitating gold with, 156; experiment in precipitating silver with, 146, 154; formation of, at Butte, Mont., 788; primary origin, 790, 791; reaction for formation of, 637; Stokes' test for, 626
Chalcocite to covellite reaction, 640
Chalcocite deposition, experimental data on, 624; in the presence of calcite, 648; volume relations in, 642
Chalcocite enrichment (Spencer), 621; chemistry of, 622

Chalcocite formation and upward secondary sulphide enrichment at Butte, Montana (Rogers), 781
Chalcocite rims, formation of, 786
Chalcopyrite, 51, 417, 423, 427; change to chalcocite, 627; experiment in precipitating gold with, 157; experiment in precipitating silver with, 146; reactions with, 625
Chalcopyrite oxidation, reactions, 633
Chamberlin, R. T., on gases in rocks, 50, 227
Chamberlin, T. C., glacial work directed by, 582
Chanacillo, Chile, analyses of fresh and altered limestones from, 221
Chandler formation, 772
Chemical analyses—alunite, 762, 763; andesite from Barth, Nev., 252; beaverite, 317; Berea sandstone, 471; greisen, 115; iron ore, 327; Barth, Nev., 257, 259; limestone and garnet from Clifton-Morenci, Ariz., 221; limestones, fresh and altered, from Bingham, Utah, 218; from Bisbee, Ariz., 220; from Chanacillo, Chile, 221; from Hastings County, Ontario; from Iron Springs, Utah, 217; from San Jose, Mexico, 221; from White Knob, Idaho, 220; peaty material, Putnam, N. Mex., 364; plumbojarosite, 314; quartz monzonite, 115, 333; Shinarump clay, 445; travertine, Wagon Wheel Gap, Colo., 243; water, from hot springs and mines, 660; from mines, 644, 645; from the hot springs of Wagon Wheel Gap, Colo., 239; zinc ores, Leadville, Colo., 16
Chemical methods of determining components of rocks, 121
Chemometer, 572
Chemung formation, 521
Cherokee shales, 774
Cherry Grove sand (natural gas), 521
Chestnut Ridge anticline, 530
Chillagoe contact zones, 603
Chinacello, Chile, ratios in unaltered and metamorphosed limestones, 503
Chlorine, in relation to concentration of gold, 500; in water, 662
Cincinnati geanticline, 534
Cinnabar, 417, 427; experiment in precipitating gold with, 157
Circulating solutions, rôle in metasomatic replacement, 62
Clapp, C. H., discussion by, 177
Clapp, F. G., *Outline of the geology of natural gas in the United States*, 517
Clarke, F. W., on analysis of water, 656, 657; on decomposition of sulphides, 425; on precipitation of argentite, 419
Classification—geologic structures on which gas accumulation exists, 529; igneous rocks, 561; methods of determining components of rocks, 121; mineral waters, 399; public lands, 337; rocks, 553; sedimentary carbonaceous rocks, 562; sedimentary rocks, 562
Clay, Shinarump, physical and chemical properties, 444
Cleark Creek County, Colorado, precious metal veins, 51
Cleveland oil pool, 774
Cleveland Stone Company's pit, 474
Clifton district, Utah, plumbojarosite, 315
Clifton-Morenci, Ariz., analyses of limestone and garnet from, 221; contact metamorphism, 32
Clinton formation, 682, 686
Clinton sand, 523
Cloez, S., on origin of natural gas, 540
Coal, literature on, 196, 303
Coal fields of King County, Washington, 97
Coal lands, examination of, 276
Coalinga gas field, California, 530
Cobalt series, 485
Cobaltite, 153, 417; experiment in precipitating gold with, 157; experiment in precipitating silver with, 147
Cœur d'Alene district, Idaho, Secondary enrichment in the Caledonia mine (Shannon), 565
Cold acid sulphate solutions of copper, silver, and gold, behavior with alkaline extracts of metallic sulphides (Grout), 407
Collecting fossils, 589, 594–597
Collection of material, 95
Collins, J. H., on origin of kaolinite, 790
Colorado natural gas, 526
Coloring maps, 750
Coloring used on drift maps, 586
Columbus formation, 682
Comet lode, Montana, 111
Comparison of analyses of fresh and altered limestones by means of the composite straight-line diagram, 215
Comparison of waters of mines and

of hot springs (Emmons and Harrington), 653
Compass for field work, 275
Compass, use in traversing, 696
Compass and pace measurement, 691
Compilation book for field notes, 176
Components of rocks, The determination of the relative volumes by mensuration methods (Lincoln and Rietz), 120
Complex and little known sulphates and sulpharsenates as ore minerals in Utah, Occurrence of (Butler), 311
Comstock lode, hot waters of, 245
Concentrate from Tomboy lode, composition, 544
Concretions, in Shinarump clays, 443
Conemaugh formation, 520
Conglomerates, fossils in, 594
Conoquenessing sand (natural gas), 521
Contact between sedimentary and crystalline rocks, natural gas at, 537
Contact metamorphic minerals, 22; relative succession, 22
Contact ore deposits, 19
Contact silicates, 600
Contact zones, 26, 597; physics and chemistry of, 215
Contacts, limestone, characteristics, 20; distribution, 20
Contact-metamorphic ore deposits, formation of the secondary silicate zone in, 501
Control, for geologic mapping, 266; quadrilateral method of, 740, 744
Cooke, H. C., on secondary enrichment, 408
Cooper sand (natural gas), 521
Copper, effect on precipitation of silver, 151; deposition of, 669; literature on, 193, 300, 807; locus of precipitation from thermal waters, 246; occurrence in Old Dominion mine, Globe, Ariz., 720; precipitation from solutions, 412
Copper, silver, and gold, cold acid sulphate solutions of, behavior with alkaline extracts of metallic sulphides (Grout), 407
Copper deposits, Lake Superior region, locus of formation, 246
Copper ore, Plumas County, California, 782
Copper sulphide, deposition of, 637
Copper-nickel deposits of Insizwa, East Griqualand, 191
Corkite, 318
Correlation of natural gas sands in central Ohio with formations in Allegheny Mountains, 539
Corson and Gish, assay by, 243
Cortez Range, Nevada, 248
Coste, E., on origin of natural gas, 540
Costs of mapping, 750
Covellite, 417, 569; action in silver sulphate solution, 155; alteration to chalcocite, 640; experiment in precipitating gold with, 157; experiment in precipitating silver with, 147; produced experimentally, 626
Cow Run sand (natural gas), 520
Cox, A. J., and Abegg, R., on relative solubility of silver salts, 152
Cragin, F. W., classification of Red beds, 772
Crane, G. W., review of work by, 399
Crawford, R. D., discussion by, 386
Creede, Colo., formations of, 236
Criteria in the study of ore deposits, recording of, 79
Criteria of replacement deposits, 261
Crosby, W. O., on contact deposits of Washington Camp, Ariz., 45; on limestone-granite contact deposits of Arizona, 21
Cross, W., on nomenclature of rocks, 555; on occurrence of alunite, 755
Cross traverse methods, 91
Cupric sulphate, reaction with chalcocite, 637
Cuprite, 417
Cuprous sulphides, effects of thin coatings of, 160
Current literature, index of, 401
Cushing pool, 774
Cutters, in Berea sandstone, 477

Dale, T. N., on commercial granites, 120
Dates of chalcocite enrichment, Ely district, Nevada, 651
Davenport and Rietz, calculation method of, 131
Davis, W. M., on the Shinarump group, 435
Day, A. L., and Shepherd, E. S., on water in Kilauean lavas, 508
Day, D. T., on oil and gas fields of the United States, 571
DeClermont and Frommel, on alkaline solutions, 425
Deertrail mine, Marysvale district, Utah, jarosite from, 320
Delaware formation, 682

Delesse, A., mensuration method of, 124
Density methods of determining components of rocks, 121, 122
Depth of enrichment, silver and gold veins of Colorado, 52
De re metallica, review of, 509
Determination of components of rocks, time required for, 138
Determination of the relative volumes of the components of rocks by mensuration methods (Lincoln and Rietz), 120
Determinative mineralogy (review of), 298
Diagrams—base expansion by auxiliary point method, 742; by broken base method, 742; composite straight-line representation of analyses, 219; graphic control net, 373; half quadrilateral method of base expansion, 743; natural gas fields on anticlines, 531; natural gas on a structural-terrace, 533; polygon method, 741, 745; progress of heat waves from a cooling latholith, 230; proportions of components in water analyses, 654, 655; quadrilateral method, 739, 745; reduction of base line, 733; triangle method, 741, 745
Diffusion phenomena, 803
Dikes of aplite, 108
Diopside, 22, 30
Dip, apparent, tables showing, 492
Dip, determining, in field work, 278
Discovery of pyrrhotite in Wisconsin, with a discussion of its probable origin by magmatic differentiation (Bogg), 369
Discussion—"Algonkian" vs. "Pre-Cambrian" (Leith), 507
Contact zones (Kemp), 597
Control for geologic mapping in the absence of a topographic base map (Stebinger), 266
Field and office methods in the preparation of geological reports (Calkins), 373; (Smith), 264; (Smith), 383
Field and office methods in the preparation of geologic reports (Moon), 795
Field and office methods in the preparation of geological reports. Geological field methods (Kemp), 171
Field methods in physiographic geology (Johnson), 713
Field methods in the "Tierra Caliente" (Hartley), 578
Field methods of geologic mapping in public land states of the west (Barnett), 272
Field methods of glacial geology (Leverett), 581
The fineness of gold in the Fairbanks district, Alaska (Knopf), 800
Formation of the secondary silicate zone in contact-metamorphic ore deposits (Stewart), 501
Fossils for stratigraphic purposes (Schuchert), 588
Hydrothermal alteration (Uglow), 797
Illustrations (Ridgway), 279
Manganese in superficial alteration (Eddingfield), 499
Measurement of the thickness of strata with the plane table and telescopic alidade (Woodruff), 291
Measurements by compass, pace, and aneroid (Barrell), 691
Metallic minerals as precipitants of silver and gold (Tovote), 720
Method of geologic mapping and note taking (Stose), 389
Methods of field work in the phosphate districts of Idaho, Montana, Wyoming, and Utah (Richards), 181
A modification of the ordinary field method (Clapp), 177
A modification of the Walcott method of measuring stratigraphic sections (Blackwelder), 489
Microstructure of titaniferous magnetites (Newland), 610
The nature of replacement (Stevens), 397
Note taking (Purdue), 712
Objects and methods of petrographic description (Berkey), 700
Penfield protractor, 373
Some methods of geologic field work (Crawford), 386
Some notes on equipment (Ball), 382
Some suggestions as to field methods (Ohern), 376
Some suggestions for general field work (Anderson), 289

Special planetable for work on a large-scale base map (Gardner), 495
The substructure of geological reports (Irving), 66
Substructure of geologic reports (Smith), 393
Tables showing apparent dip of structure planes in any vertical section (Mosier), 492
Term protore suggested (Ransome), 721
Dissociation of calcium carbonate, 224
Dixie copper mine, Washington Co., Utah, jarosite from, 320
Dolcoath mine ore body, Elkhorn, Mont., 324
Dole, R. B., review by, 399
Doelter, C., on solution of sulphides, 429
Dome mine, Porcupine district, Ontario, 482, 483
Domestic use of water, 339
Don, J. R., on insolubility of gold in ferric sulphate solutions, 801
Downward sulphide enrichment, Metasomatism in (Bastin), 51
Drill holes, Barth, Nev., logs of, 256
Drilling in Oklahoma, 775; cost of, 780
Dry-farming, 345
Dugway Range, Utah, plumbojarosite, 316
Duncan oil pool, Oklahoma, 777
Dunn, E. J., on Mt. Morgan gold, 801
Dunton, Colo., hot waters, 245
DuToit, A. L., review of work by, 191
Dutton, C. E., on the Shinarump group, 434

Eakle, A. S., on apatite, 262
Economic geology of the Berea sandstone formation of northern Ohio (Burroughs), 469
Eddingfield, F. T., discussion by, 499
Editorial—Field work (Irving), 64–65
Geological reports (Irving), 64
Edwards, M. G., review by, 399
Eldridge, G. H., on gas fields of California, 530
Electra oil field, Texas, 189, 777
Electric current, use in oxidation and reduction, 143
Electrochemical activity between solutions and ores (Wells), 571
Elizabeth or Sixth sand (natural gas), 521
Elk sand (natural gas), 521
Elkhorn, Montana, A magmatic sulphide ore body at (Knopf), 323
Elkhorn, Montana, magmatic contraction, 36; relation of garnet to limestone, 36
Elkhorn mine ore body, Elkhorn, Mont., 325
Ellis formation, 106
Elsden, J. V., on dissociation of calcium carbonate, 225
Ely district, Neveda, copper ores, 622
Emerton, F. A., analysis by, 471; methods of quarrying, 471
Emmons, S. F., on Butte chalcocite, 789; on chalcocite at Butte, 789; on ores of Cobalt district, 166; on sulphide enrichment, 621, 781; on secondary enrichment, 408
Emmons, W. H., on analyses of mine waters, 657; an alkalinity of mine waters in depth, 659; on decreasing acidity of water in copper mines, 647; on enrichment of sulphide ores, 408, 781; on iron ore deposit at Palisade, Nev., 247; on manganese in superficial alteration, 499; on mine waters, 426; on primary magnetite and hematite, 262; reviews by, 98, 722
Emmons, W. H., and Harrington, G. L., *A comparison of waters of mines and of hot springs*, 653
Emmons, W. H., and Larsen, E. S., *The hot springs and the mineral deposits of Wagon Wheel Gap, Colorado*, 235; on hot springs at Wagon Wheel Gap, Colo., 667
Enargite, 420, 427; experiment in precipitating gold with, 158; experiment in precipitating silver with, 148
Engler, C., on origin of natural gas, 540
Enid formation, 772
Enrichment, depth of, in silver and gold veins of Colorado, 52; by metasomatic replacement, silver ore, Colorado, 54; of gold veins, 501; of sulphide ores, 407; secondary sulphide, 456; definition, 781
Enrichment, Chalcocite (Spencer), 621
Enrichment, downward sulphide, Metasomatism in (Bastin), 51
Enrichment, Upward secondary sulphide, and chalcocite formation at Butte, Montana (Rogers), 781
Epidote, 22
Equipment for field work, 72, 376, 382

Errors in results, 693
Etched sections of ore, 674, 676
Eureka-Volcano-Burning Springs anticline, West Virginia, 530
Evans, G. W., review of work by, 97
Evening Star prospect, Patagonia, Ariz., 753
Experiments—in formation of chalcocite, 626; on vadose synthesis of pyrite, 455; synthesis of pyrite, 462; with acid silver solutions, 151; with alkaline solutions, 427; with gold, 156; with silver benzol sulphonate, 152; with silver sulphate solutions, 144; with sulphate solutions, 410
Experimental data on chalcocite deposition, 624
Exterior triangle method, 742

Fabre series, 486
Fairbanks district, Alaska, The fineness of gold in the (Smith), 449
Fairchild, J. G., analysis by, 327
Farrell, J. H., review of work by, 98
Fenner, C. N., on replacement of rhyolite porphyry by stephanite and chalcopyrite, 60
Ferric sulphate, precipitating action of, 420, 421
Ferrous sulphate, precipitating action of, 419
Field equipment, 275
Field geology, practical, 98
Field measurements, 77
Field methods, 264, 272, 289, 376; geological, 171, 177, 181; in "Tierra Caliente," Mexico, 578
Field notes, recording, 383
Field party, make-up of, 587
Field work, 392; scheme of, 68
Field work methods, 386
Fifty-foot sand (natural gas), 521
Fineness of gold, 800
Fineness of gold in the Fairbanks district, Alaska (Smith), 449
Finlayson, A. M., on gold and silver in sulphide ores, 167
Fire determination of zinc ore, 17
Fish Springs district, Utah, plumbojarosite, 315
Fluorite, 22, 241, 242, 243
Formation of the secondary silicate zone in contact-metamorphic ore deposits, 501
Fossilization, modes of, 590
Fossils for stratigraphic purposes, 588; occurrence of, 592
Foster, William, *A remarkable carbonaceous deposit near Putnam, New Mexico*, 360
Fraser, Colin, and Bell, J. M., review of work by, 722
Freeport sandstone, 520
Frequency distribution, 131
Fuchs, E., and Launay, L. de, on sulphide enrichment, 781

Gabbro dike, 370
Gagnon mine, Butte City, Mont., native silver in, 162
Gale, H. S., acknowledgment of help from, 752
Gale telescopic alidade, 183
Galena, 51, 417, 427; current produced in potassium chloride, 573; experiment in precipitating gold with, 158; experiment in precipitating silver with, 148
Galena mine, Utah, plumbojarosite, 316
Gannett, Henry, on topographic sketching, 749
Gantz sand (natural gas), 521
Gardner, J. H., discussion by, 495
Garnet, 325, 326; formation of, 607
Garnet rock, occurrence, 28
Garnet zones, 47
Garnetization, 47; Elkhorn, Montana, 36
Gas and oil wells near Oberlin, Ohio (Hubbard), 681
Gas in Oberlin field, composition and nature, 690
Gas fields, geographic distribution of, 517
Gas-producing regions, 518
Gay-Lussac, L. J., on decomposition of calcium carbonate, 224
Geanticlinal folds, gas fields on, 534
General and theoretic, literature on, 201, 304
Geographic distribution of gas fields, 517
Geologic boundaries, indication of, 82
Geologic data, delineation on field sheet, 750
Geologic field work methods, 386
Geologic horizons of natural gas, 527
Geologic mapping, The plane-table in, with especial reference to graphic horizontal control by intersection methods (Higgins), 729
Geologic mapping, 266, 389; in public land states, 272
Geologic map, making of, in field work, 388
Geologic maps, coloring, 283

Geologic maps—West iron mine, Palisade, Nev., 250
Geologic position, 749
Geologic reports, preparation of, 264; steps in preparation of, 67; substructure, 66
Geologic section, Oberlin, Ohio, 681
Geologic structure, necessary for natural gas accumulation, 528; of Mid-Continent oil fields, 778
Geologic surfaces, 88
Geologische Diffusionen, 803
Geology—Berea sandstone region, 478; Bovard district, Nevada, 757; Elkhorn, Montana, 323; Helena mining region, 105; Mountain, Wisconsin, 369; Palisade, Nev., 252; Patagonia district, Ariz., 753; Waihi-Tairua subdivision, Hauraki, New Zealand, 722; soils and substrata, review of, 520
Geology of natural gas in the United States, Outline of the (Clapp), 517
Gibbony, Harry, plane-table made by, 497
Giffin, C. E., time traverse, 394
Gilbert, G. K., on the Shinarump group, 434
Gilpin County, Colorado, copper ore, 628; precious metal veins, 51
Glacial drift, Oberlin, Ohio, 681
Glacial geology, mapping of, 584
Glacial investigations, 583
Globe, Ariz., contact metamorphism, 35
Gold, deposition of, 669; electrochemical action, 574; fineness of, 800; in Colorado ores, 51; locus of precipitation from thermal waters, 246; precipitation of, 418; refining by stream action, 802
Gold, fineness of, in the Fairbanks district, Alaska (Smith), 449
Gold, native, association with sulphides, 166
Gold and silver, literature on, 194, 301, 808
Gold and silver, Metallic minerals as precipitants of (Palmer and Bastin), 140
Gold of the Shinarump at Paria (Lawson), 434
Gold, silver, and copper, cold acid sulphate solutions of, behavior with alkaline extracts of metallic sulphides (Grout), 407
Gold content of Shinarump clay, 446
Gold deposits of Porcupine district, Ontario (Hore), 482
Gold Hill mine, Utah, plumbojarosite, 315
Gold ore, Porcupine district, microscopic characteristics, 483; mode of occurrence, 483
Gold Pen mine, Bovard district, Nevada, 757; alunite from, 759
Golden Curry mine, Elkhorn, Mont., 326
Goldschmidt, Victor, on contact zones, 598
Gonzalo, on secondary sulphide enrichment, 781
Goose Creek, Colorado, hot springs, 235
Gordon, C. H., on classification of metamorphic rocks, 563
Gordon Stray sand (natural gas), 521
Gottschalk, V. H., and Buehler, H. A., on electrolytic action, 61; on oxidation of sulphides, 143, 571, 632
Gould, C. N., *Petroleum in the red beds*, 768
Gradational rocks, The quantitative mineralogical classification (Lincoln), 551
Grade of zinc ores, determining, 12–15
Granite, 369, 552, 556; measurement by intercept method, 131
Granodiorite, 552
Graphic control, rules of, 739
Graphic control net, 735
Graton, L. C., and Murdock, J., on sulphide ores of copper, 628; on primary chalcocite, 789
Gray sand (natural gas), 521
Grazing lands, 342
Greer formation, 772
Gregory, J. W., on origin of kaolinite, 790
Gregory lode, Montana, 111
Grindstones, manufacture of, 473
Grossularite, 22, 28, 599, 600
Ground water and springs, 399
Grout, F. F., *On the behavior of cold acid sulphate solutions of copper, silver, and gold with alkaline extracts of metallic sulphides*, 407; on formation of sulphides of secondary enrichment zone, 782; on oxidation of pyrite, 408
Gypsum, 685
Gypsum veins, Utah, 438

Half quadrilateral method of base expansion, 743
Harder, E. C., on iron ores of California, 21, 45

Harker, Alfred, on the Shap granite of Westmoreland, 599
Harrington, G. L., and Emmons, W. H., *A comparison of waters of mines and of hot springs*, 653
Harris, G. D., on geologic mensuration, 278
Hartley, Burton, discussion by, 578
Harvie, Robert, on geology of Fabre township, 486
Hastings Co., Ont., ratios in unaltered and metamorphosed limestone, 503
Hastings County, Ontario, analyses of fresh and altered limestones from, 217
Hatch, F. H., on classification of rocks, 552
Hatschek, E., and Simon, A. L., on gels in relation to ore deposition, 550
Hawkins, F. W., fineness of Fairbanks gold, 449
Hayes, C. W., on recording geologic data, 749
Heat conditions accompanying an intrusion, 228
Helena, Mont., ore deposits, 109
Helena mining region, geologic environment, 105
Hematite, 10, 257, 400
Henriette ore-body, Leadville, Colo., 4
Heroy, W. B., *Land classification, its basis and methods*, 337
Hershey, O. H., on the Caledonia vein, 565
Hess, F. L., review by, 401
Heumann, on precipitation of silver, 155
Hewett, D. F., review by, 189
Higgins, D. F., *The plane-table in geologic mapping with especial reference to graphic horizontal control by intersection methods*, 729
Hill, R. T., on occurrence of alunite, 755
Hillebrand, W. F., and Penfield, S. L., on natroalunite, 763; on plumbojarosite, 311
Hillebrand, W. F., and Wright, F. E., on plumbojarosite, 312
Histometabasis, 590
Höfer von Heimhalt, Hans, review of work by, 399; on origin of natural gas, 540
Holden, R. J., on iron ores of Virginia, 49
Hollinger mine, Porcupine district, Ontario, 482
Holocrystalline rocks, 561
Holsinger, S. J., on occurrence of carbonaceous deposit, 361
Homewood sandstone, 520
Hoover, H. C., and Hoover, L. H., review of translation of Agricola's work, 509
Hore, R. E., *Gold deposits of Porcupine district, Ontario*, 482
Horizontal control, 731
Horizontal distances, measurement by aneroid, 732
Horizontal position, 732; determination by intersection methods, 733
Horn Silver mine, Beaver Co., Utah, beaverite from, 316
Hot springs and mineral deposits of the Wagon Wheel Gap, Colorado (Emmons and Larsen), 235
Hot springs and mines, A comparison of waters of (Emmons and Harrington), 653
Hot springs, waters of, 664; Wagon Wheel Gap, Colorado, curative powers, 235, 237
Hot waters, analyses of, 650
Hubbard, G. D., *Gas and oil wells near Oberlin, Ohio*, 681
Humboldt, on origin of natural gas, 540
Hundeshagen, L., on platinum in wollastonite, 21
Hundred-foot sand (natural gas), 521
Hunt, T. S., on anticlinal theory, 542; on origin of natural gas, 540
Hunter, J. F., review by, 614
Hurlbut, E. B., on alunite from Red Mountain, Colo., 764
Huronian series, 485
Hurry-up sand (natural gas), 520
Hyaline rocks, 561
Hydrochloric acid, action on ilmenite and magnetite, 208
Hydrogeology, underground, 399
Hydrothermal alteration, 797
Hydrozincite, 8
Hypotheses on the origin of the secondary silicate zones at the contacts of intrusives with limestones, Review of (Uglow), 19, 215

Iceberg hypothesis, 582
Iddings, J. P., on phlogopite, 262
Igneous rocks, textural classification, 561
Illinois natural gas fields, 524
Illustrations, 279
Ilmenite, 208, 611, 678; microphotographs of, 210; section of, 672; separation from magnetite, 208

Index of current literature, 401
Indexing field notes, 180
Indiana natural gas fields, 524
Ingersoll, L. R., data on thermal conductivity, 228, 230; on a cooling magma, 608
Instrumental methods, field work, 182
Intersection methods of determining horizontal position, 733
Intervisibility of stations in topographic surveying, 736
Intrusions, heat conditions accompanying, 228
Iron, in water, 663; literature on, 194, 301, 812
Iron deposits of West, origin, 26
Iron hydroxide, reaction, 633
Iron ore, analysis, 327; Barth, Nevada, 257; analyses, 257, 259; origin, 259; Elkhorn, Mont., 324, 326
Iron ore deposit, Palisade, Nev., 247
Iron ore deposit, The Barth (Jones), 247
Iron ores, Lake Sanford, 611; of Missouri, 399
Iron Springs, Utah, analyses of fresh and altered limestones, 217; contact minerals, 40; iron ore deposit, 263; ratios in unaltered and metamorphosed limestones, 502
Irrigability of public lands, 343
Irrigation reservoirs, 349
Irrigation rights of way, 357
Irving, J. D., editorial on field work, 64; on replacement ore bodies, 261
Irving, R. D., on pyrite in Wisconsin, 370

Jacquelain, Y. A., on decomposition of calcium carbonate, 224
Jacquemin mine, Elkhorn, Mont., 326
Jamesonite, 417; experiment in precipitating silver with, 148
Jarosite, 315, 320
Johnson, D. W., discussion by, 713
Johnson Run sand (natural gas), 520
Joint cracks, natural gas in, 537
Jones, J. C., *The Barth iron ore deposit*, 247
Jordan, G. W., chemical analysis by, 785
Julien, A. A., mensuration method of, 124

Kane sand (natural gas), 521
Kansas natural gas fields, 524
Kaolin, literature on, 197
Kaolinite, origin, 790
Katamorphism, 49
Keewatin series, 485, 486
Kemp, J. F., *Artificial vein-formation in the Tomboy mill, Telluride, Colorado*, 543; discussions by, 171, 597; on contact deposits, 24, 45, 216; on contact metamorphism, 227; on copper deposits of San Jose, Mexico, 22, 45; on field data, 714; on rocks of eastern Adirondacks, 45
Kemp, J. F., and Gunther, C. G., on copper deposits of Mackay, Idaho, 22; on White Knob copper deposits, 45
Kentucky natural gas fields, 522
King County, Washington, coal fields of, 97
Kirk, C. T., on Butte chalcocite, 789
Kirkwood sand (natural gas), 524
Knight, C. W., and Burrows, A. G., on rocks of Porcupine district, 486
Knopf, Adolph, *A magmatic sulphide ore body at Elkhorn, Montana*, 323; *The tourmalinic silver-lead type of ore-deposit*, 105; discussion by, 800; on ore deposits of Helena region, Mont., 325; on secondary silicates in Seward Peninsula, 501; review by, 803
Knopf, Adolph, and Umpleby, J. B., *Recent literature on economic geology*, 193
Königsberger, J., on dissociation of calcium carbonate, 223

Labradorite, 333
Lake Sanford iron ores, 611
Lancaster Gap pyrrhotite, analysis, 370
Land classification, its basis and methods (Heroy), 337
Laney, F. B., on chalcocite and bornite, 789
Laramie formation, 363
Larsen, E. S., on occurrence of alunite, 755
Larsen, E. S., and Emmons, W. H., *The hot springs and the mineral deposits of Wagon Wheel Gap, Colorado*, 235; on hot springs at Wagon Wheel Gap, Colo., 667
Laurentian, 485
Law of equal volumes, 397
Lawson, A. C., *The gold of the Shinarump at Paria*, 434; on composition of mine water, 645; on copper deposits of Robinson mining district, Nevada, 45; on formation of contact deposits, 25
Lawson silver mines, Colorado, 52

Lawton oil pool, Oklahoma, 777
Lead and zinc, literature on, 195, 302, 813
Leadville, Some recent developments at; the oxidized zinc ores (Butler), 1
Leadville, Colo., ores, 1; zinc ores, geologic position, 4; origin, 9
Le Chatelier, H., on temperature-pressure relations, 224
Lee Mountain mine, Montana, 111
Lehner, Victor, on deposition of gold, 668
Leith, C. K., discussion by, 507; on formation of contact metamorphic minerals, 25; on reduction of volume by contact metamorphism, 223
Leith, C. K., and Harder, E. C., on iron ores of Utah, 21, 23, 46, 263, 610
Leona Heights pyrite deposit, 455
Leucocratic minerals, 552
Leucous rocks, 558
Leverett, Frank, discussion by, 581
Lewis, J. V., review of work by, 298
Lewis shale, 363
Liesegang, R. E., review of work by, 803
Limestone contacts, characteristics, 20; distribution, 20
Limestones, analyses of, 217, 218, 220
Linarite, 321
Lincoln, F. C., *The quantitative mineralogical classification of gradational rocks*, 551; mensuration method of, 125
Lincoln, F. C., and Rietz, H. L., *The determination of the relative volumes of the components of rocks by mensuration methods*, 120
Lindgren, W., on alunitization, 756; on classification of rocks, 552; on Clifton-Morenci district, 45; on contact deposits, 46, 216; on copper deposits of Seven Devils, 21; on copper ores of Clifton-Morenci, 21, 23, 25; on fineness of gold in Tertiary gravels, 454; on formation of contact metamorphic minerals, 25; on hot springs of Ojo Caliente, N. Mex., 244, 245, 667; on metamorphic effects of basic rocks, 227; on metasomatic processes, 245; on natural refining of gold, 169; on nature of replacement, 61; on ore deposition, 669; on origin of gold quartz veins, 487; on pyrite oxidation, 633; on replacement, 643; on secondary sulphide enrichment, 458; review by, 191
Lindgren, W., Graton, L. C., and Gordon, C. H., on ore deposits of New Mexico, 45
Lindley sand (natural gas), 524
Literature, current, index of, 401
Literature on economic geology, Recent (*see* Recent literature, etc.)
Literature on precipitation of precious metals by sulphides, 141
Lithium, 239
Lithium, in water, 663
Little Giant silver mine, Colorado, 52
Lloyd, E. R., and Paige, Sidney, *Recent literature on economic geology*, 807
Location, methods of, in field work, 379
Loco oil pools, Oklahoma, 777
Loew, O., on hydrogen sulphide in hot spring, Colorado, 238
Lorain Co., Ohio, Berea sandstone industry, 473
Los Angeles gas field, California, 530
Louisiana natural gas fields, 525

McCarty, E. T., on wollastonite ore deposits of Chiapas, 21
McCloskey sand (natural gas), 524
McKenzie Mountain, Colorado, formations of, 236
Macksburg gas field, Ohio, 532
Magmatic segregations, diagnosis of, 80
Magmatic sulphide ore body at Elkhorn, Montana (Knopf), 663
Magnesium, in water, 663
Magnetic declination, determination of, for field work, 184
Magnetite, 21, 208, 325; microphotographs of, 210; section of, 672
Magnetite, titaniferous, Some notes on (Brunton), 670
Magnetites, titaniferous, The microstructure of (Singewald), 207
Magnetites containing titanium, 611
Maine granite, measurement by intercept method, 131
Manganese in superficial alteration, 499
Map, for field work, 291, 377, 389; preparation of, for field work, 172, 177; subdivision for recording field notes, 174, 177
Map making, in field work, 384
Mapping, geologic, The plane-table in, with especial reference to graphic horizontal control by intersection methods (Higgins), 729

Mapping, for geologic work, 268; glacial geology, 584; scale for field work, 268
Maps—Nevada, showing location of Palisade, 249; West iron mine, Palisade, Nev., 248
Maps, recording data on, 84
Maquenne, L., on origin of natural gas, 540
Marcasite, 427, 460; current produced in potassium chloride, 573; experiment in precipitating gold with, 158; experiment in precipitating silver with, 148
Marysvale, Utah, alunite, 763
Marysvale district, Piute Co., Utah, plumbojarosite from, 315
Marysvale, Mont., contact metamorphism, 42
Material, collection of, 95
Mathews, J. A., on origin of natural gas, 540
Maude-S. vein, Empire Station, Colo., ore, polished section, 57
Maxon sand (natural gas), 521
Mead, W. J., on composite straight-line representation, 218
Measuring stratigraphic sections, 489
Measuring thickness of strata, 291
Measurements in field work, 77
Medina formation, 686
Meinzer, O. E., review by, 615
Melanocratic minerals, 552
Melanous rocks, 558
Mendeleff, D. I., on origin of natural gas, 540
Mennell, F. P., review of work by, 614
Mensuration methods, The determination of the relative volumes of the components of rocks by (Lincoln and Rietz), 120
Mental preparation for field work, 715
Mesaverde formation, 363
Mesocratic rocks, 553
Metallic minerals as precipitants of silver and gold (Palmer and Bastin), 140
Metamorphic rocks, classification of, 563
Metamorphism, at Elkhorn, Mont., 324; selective, 47
Metasomatic replacement, 643; silver ore, Colorado, 54
Metasomatism, 398
Metasomatism in downward sulphide enrichment (Bastin), 51
Methylen iodide, use in determining grade of zinc ore, 15
Meunier, S., on precipitation of silver, 155
Microphotographs—andesite showing penetration of crevices, 260; cemented concentrate, 546–549; ilmenite and magnetite, 210; magnetite and ilmenite crystals, 672; plumbojarosite, Beaver Co., Utah, 313; pyrrhotite-augite ore, 328; pyrrhotite-chalcopyrite ore, 329; pyrrhotite-augite diorite, 331
Microscope, in measurement of components of rocks, 123
Microstructure of titaniferous magnetites (Singewald), 207
Mid-Continent oil fields, 769; geologic structure, 778
Miller, H. E., analysis by, 645
Millerite, 417, 427; experiment in precipitating gold with, 158; experiment in precipitating silver with, 149
Mine waters, 665; action of, 169; alkaline, 425; composition, 644
Mines, waters of, and of hot springs, A comparison of (Emmons and Harrington), 653
Mineral deposits and hot springs of the Wagon Wheel Gap, Colorado (Emmons and Larsen), 235
Mineralogical classification, The quantitative, of gradational rocks (Lincoln), 551
Mineralogy, determinative (review of), 298
Minerals, contact metamorphic, 22; relative succession, 22
Minerals, metallic, as precipitants of silver and gold (Palmer and Bastin), 140
Mining districts, field work in, 73
Minshall, on anticlinal theory, 542
Missouri natural gas fields, 525
Modoc formation, Clifton-Morenci, Ariz., alteration in, 32
Molybdenite, 417
Monoclinal structure of gas fields, 532
Monroe group, 682
Moon, F. W., discussion by, 795
Moore, E. S., on hydrothermal alteration, 797
Morenci, Ariz., ratios in unaltered and metamorphosed limestones, 503
Morley, W. S., assays by, 447
Moscow mine, Utah, plumbojarosite from, 315
Moses, A. J., review of work by, 98
Mosier, Henry, discussion by, 492

Motorcycle, use in surveying work, 692
Mt. Morgan, Australia, fineness of gold, 800
Mountain, Wisconsin, deposit of pyrrhotite, 369; analysis, 370
Multiple exposure method, 92
Multiple hypotheses method, use in field work, 719
Murdock, J., and Graton, L. C., on sulphide ores of copper, 628
Murraysville sand (natural gas), 521
Muscovite, 22

Naco limestone, Bisbee, Ariz., 32
Napoleon sandstone, 479
Native gold, association with sulphides, 166
Native silver, association with cobalt and nickel arsenides, 165; association with copper ores, 161
Natroalunite, 763
Natural gas, geologic horizons of, 526; from oil pools, 537; literature on, 198; origin, 540; production in the United States, 518; in Oberlin field, composition and nature, 690
Natural gas in the United States, Outline of the geology of (Clapp), 517
Natural gas accumulation, conditions necessary for, 526
Neihart, Mont., sulphide enrichment, 58
Newberry, J. S., on origin of natural gas, 540
Newland, D. H., discussion by, 610
New Malone quarry, Ohio, 474
Newton, Edmund, assay by, 243
New York gas fields, 520
Niagara group, 682
Niccolite, 409, 417, 427; as precipitant of silver and gold, 140; composition, 153; experiment in precipitating gold with, 158; experiment in precipitating silver with, 149, 153
Nicholsonite, 8
Ninevah Thirty-foot sand (natural gas), 521
Nomenclature of igneous rocks, 555
Norite-diorite, Plumas County, Cal., 782
North Dakota natural gas fields, 526
Note-book for field use, 176, 377
Note-book records, in field work, 388
Note-books, making records in, 264
Note taking, 389, 712, 714
Notes, recording, 87, 172, 179, 187
Notes on titaniferous magnetite, Some (Brunton), 670

Oberlin, Ohio, Gas and oil wells near (Hubbard), 681
Occurrence of complex and little known sulphates and sulpharsenates as ore minerals in Utah (Butler), 311
Office methods, 264
Office work on geological reports, 96
Ohern, D. W., discussion by, 376
Ohio-Clinton sea, 689
Ohio natural gas fields, 522
Ohio Quarries Company's pit, 474
Oil and gas, literature on, 198, 303
Oil and gas fields of Wichita and Clay counties, Texas, 189
Oil and gas wells near Oberlin, Ohio (Hubbard), 681
Oil in northern area of Mid-Continent field, 773
Oil in southern area of Mid-Continent field, 777
Oil sands, 768
Ojo Caliente, New Mexico, hot springs, 244, 245
Oklahoma, deep drilling in, 775; natural gas fields, 525
Old Dominion mine, Globe, Ariz., 720
Old Glory mine, Nevada, 648
Old Malone quarry, Ohio, 474
Olentangy, 682
Oliphant, F. H., on natural gas pressure, 520
On the behavior of cold acid sulphate solutions of copper, silver, and gold with alkaline extracts of metallic sulphides (Grout), 407
Ophir district, Tooele Co., Utah, plumbojarosite, 316
Ore deposit, The tourmalinic silver-lead type of (Knopf), 105
Ore deposits, along limestone contacts, 21; at Elkhorn, Mont., 324; modes of formation of, 653
Organ Mountains, garnetization, 39
Origin—alunite, 764; cutters in Berea sandstone, 477; gold deposits of Porcupine district, 486; iron ore, Barth, Nev., 259; of natural gas, 540; of ore minerals, 23; of pyrrhotite ore body, Elkhorn, Mont., 334; Red beds, 770; secondary silicate zones, 19, 28–44; of silicate minerals, 23; Wisconsin pyrrhotite, 371; zinc ore, Leadville, Colo., 9
Orpiment, 417, 427; experiment in precipitating silver with, 149

Orton, Edward, on terrace structure, 532; on origin of natural gas, 540
Ostwald, W., on the chemometer, 572
Outfit, for field mapping, 267; for field work, 376
Outline for petrographic description, 705
Outline of the geology of natural gas in the United States (Clapp), 517
Oxidation, by cupric sulphate, 636; by ferric sulphate, 634; by free oxygen, 632
Oxidation and reduction current with electrodes of pyrite, 572
Oxidized zinc ores at Leadville (Butler), 1
Oxygen, source of, in ground water, 630

Pace and compass measurement, 691
Pacing, efficiency in, 697
Paige, Sidney, and Lloyd, E. R., *Recent literature on economic geology*, 807
Palisade, Nev., iron ore deposit, 247
Palmer, W. S., analyses by, 252, 257, 644
Palmer, Chase, on interpretation of water analysis, 645, 658
Palmer, Chase, and Bastin, E. S., *Metallic minerals as precipitants of silver and gold*, 140; on deposition of silver by chalcocite, 574; on precipitants of gold and silver, 408
Paragenesis of minerals, 505
Paria, The gold of the Shinarump at (Lawson), 434
Paria, Utah, location, 436
Party for field work, personnel of, 274
Patagonia, Arizona, alunite in (Schrader), 752; location, 752; geology, 753
Paymaster mine, Washington Co., Utah, minerals from, 319
Peale, A. C., on analyses of water, 656
Pearce, Richard, on silver associated with copper, 162
Peat, average composition, 364
Peckham, S. F., on origin of natural gas, 540
Penfield protractor, 373
Pennsylvania gas fields, 520
Petrographic description, objects and methods, 700; outline for, 705
Petrography, 702
Petroleum in the Red beds (Gould), 768
Petrolia oil field, Texas, 189, 777
Petrology, manual of (review of), 614
Phlogopite, 255
Phosphate districts, field work methods in, 181
Photographs, for illustrations, 286; in field work, 396; in note-books, 265
Physiographic geology, field methods in, 713
Pipes of iron-lime silicates in an eruptive, 601
Placer gold, fineness of, 449
Placers and lodes of Alaska, location, 449
Plane-table, 182; special, for large-scale map, 495
Plane-table in geologic mapping with especial reference to graphic horizontal control of intersection methods (Higgins), 729
Plumas County, Cal., ore-minerals, 782
Plumbojarosite, 311; analyses, 314
Pocono formation, 521
Polarization, 575
Polishing of sections of ore, 673
Polybasite, 51, 54
Polygon method of surveying, 741
Ponca City pool, 774
Porcupine district, Ontario, Gold deposits of (Hore), 482
Porphyritic rock, Palisade, Nev., 251
Porphyry ore, decomposition of, 636
Port Leyden, N. Y., magnetites, 613
Position, geologic, 749; horizontal, 732; determination by intersection methods, 733; three elements of, 731; vertical, determination of, 748
Potash, from alunite, 766
Potassium, in water, 663
Potosi volcanic series, Colorado, 235
Pottsville formation, 520
Powell, J. W., on irrigation, 343; on the Shinarump group, 434
Power stream, 351
Practical field geology, 98
Pre-Cambrian and Algonkian, 508
Pre-Cambrian granite, 369
Precipitants of silver and gold, Metallic minerals as (Palmer and Bastin), 140
Precipitates from acid silver sulphate and alkaline antimony sulphide solutions, analyses of, 429
Precipitation, causes of, 669; of copper and gold, locus of, 246; of precious metals by sulphides, 141

Preglacial erosion of Berea sandstone, 480
Preparation for field work, 70, 183, 715
Princess of India tunnel, Lawson, Colo., ore, polished section, 53, 55
Prindle, L. M., and Katz, F. J., on gold of Ready Bullion Creek, 449
Profile traverse method, 92
Projection, for mapping, 284
Prospecting for alunite, 766
Prosser, C. S., classification of Red beds, 772
Protore, definition of, 721
Protractor, Penfield, 373
Proustite, 51
Pseudomorph, 591
Psilomelane, 9
Purington, C. W., on mineralogy of Tomboy lode, 543
Putnam, New Mexico, A remarkable carbonaceous deposit near (Foster), 360
Pyrite, 51, 242, 370, 417, 427, 460, 482; change to chalcocite, 627; efficiency in precipitating silver, 145; experiment in precipitating gold with, 158; experiment in precipitating silver with, 149; synthesis of, apparatus for, 462
Pyrite, The vadose synthesis of (Whitman), 455
Pyrite electrodes, oxidation and reduction current, 572
Pyrite oxidation, reactions, 633
Pyrite-chalcocite series of minerals, 638
Pyroxene, 329
Pyrrhotite, 417, 427; analyses, 370; experiment in precipitating gold with, 158; experiment in precipitating silver with, 149; precipitation of copper by, 413
Pyrrhotite in Wisconsin, The discovery of, with a discussion of its probable origin by magmatic differentiation (Bagg), 369
Pyrrhotite ore body, Elkhorn, Mont., 327

Quadrilateral method of control, 740, 744
Quantitative experiments with silver solutions, 153
Quantitative mineralogical classification of gradational rocks (Lincoln), 551
Quantitative system scheme, 707
Quaquaversal structure, 534
Quarrying of Berea sandstone, 471
Quartermaster formation, 771, 772
Quartz, 22, 298, 482
Quartz monzonite, 107, 115, 552; Elkhorn, Mont., 333; analysis, 333
Quartz veins, 0[illegible]
Queen mine ore body, Elkhorn, Mont., 111, 325

Railroad rights of way, 356
Random sampling theory, 129
Ransome, F. L., discussion by, 721; on Bisbee district, 45; on copper ores of Bisbee, 21; on downward sulphide enrichment, 430, 458; on enrichment at Bisbee, 793; on Globe district, Ariz., 45; on Goldfield deposits, 425; on metamorphic action of diabase, 227; on mineralogy of Tomboy lode, 543; on occurrence of alunite, 755; on ore deposits of Breckenridge district, Colo., 23; on secondary chalcocite, 643; on secondary sulphide enrichment, 781; on the plane-table, 182; review by, 509
Ransome, F. L., and Wegemann, C. H., on the three-point problem, 185
Reacting values, in water analyses, 659
Reactions, in formation of zinc ore, 9–10; with alkaline solutions, 426
Read, T. T., on chalcocite deposition, 624; on copper-iron sulphides, 628
Realgar, 417, 427; experiment in precipitating silver with, 150
Recent literature on economic geology, 193, 300, 807
Reclamation act, 344
Reconnaissance, preliminary, in field work, 289
Recording field notes on map, 387
Recording notes of field work, 172, 179, 184, 389, 585
Records of field work, recording of, 75
Recrystallization hypothesis of contact minerals, 28
Recrystallization in formation of secondary silicates, 506
Red beds, Petroleum in the (Gould), 768
Red beds, area, 769; origin, 770; stratigraphy, 771; structural features, 773; thickness of, 774, 775
Red Mountain, Colorado, alunite, 763
Red Warrior mine, Utah, plumbojarosite from, 315
Refining of gold by stream action, 802

Regional geology, literature on, 200, 304
Relative volumes of the components of rocks, The determination of, by mensuration methods (Lincoln and Rietz); 120
Remarkable carbonaceous deposit near Putnam, New Mexico (Foster), 360
Replacement, nature of, 397; of andesite by iron ore, 260; of minerals, nature of, 61
Review of the existing hypotheses on the origin of the secondary silicate zones at the contacts of intrusives with limestones (Uglow), 19, 215
Reviews—The coal fields of King County, Washington (Evans), Campbell, 97
Copper-nickel deposits of the Insizwa, Mount Ayliff, East Griqualand (DuToit), Lindgren, 191
De re metallica (Agricola, trans. by Hoover and Hoover), Ransome, F. L.
Determinative mineralogy, with tables for the determination of minerals by means of their chemical and physical characters (Lewis), Schaller, 298
Geologische Diffusionen (Liesegang), Knopf, 803
Geology of soils and substrata (Woodward), Shaw, 510
Geology of the Waihi-Tairua subdivision, Hauraki, Auckland (Bell and Fraser), Emmons, 722
Ground water and springs; underground hydrology (Höfer von Heimhalt), Dole, 399
The iron ores of Missouri (Crane), Edwards, 399
Manual of petrology (Mennell), Hunter, 614
The Mining World index of current literature (Sisley), Hess, 401
Practical field geology (Farrell), Emmons, 98
Reconnaissance report on the geology of the oil and gas fields of Wichita and Clay counties, Texas (Udden and Phillips), Hewett, 189
Ueber Kappenquarze (Beck), Singewald, 298
Underground water resources of the Coastal Plain province of Virginia (Sanford), Meinzer, 615
Rhodochrosite, 51
Rhyolite, 236, 759
Richards, R. W., discussion by, 181
Richards barograph, 699
Rietz, H. L., and Lincoln, F. C., *The determination of the relative volumes of the components of rocks by mensuration methods*, 120
Right of way acts, 355
Rimini, Mont., silver-lead deposits, 111
Robinson district, Nev., silicate zones, 603
Robinson mining district, Nevada, contact minerals, 37
Robinson sand (natural gas), 524
Rocks, gradational, The quantitative mineralogical classification (Lincoln), 551
Rogers, A. F., *Upward secondary sulphide enrichment and chalcocite formation at Butte, Montana*, 781; on dahlite, 262
Rosenbush, H., on origin of ore minerals, 23
Rosin Jack, 417, 427
Rosiwal, A., linear mensuration method of, 125, 127
Rösler, H., on origin of kaolinite, 790
Ross, O. C. D., on origin of natural gas, 540
Rules of graphic control, 739
Rumbold, W. R., on tourmaline in Bolivian ores, 118
Ruth mine, composition of water from, 645
Rutile, 678

Sabine uplift, Louisiana, 525
Sacrificio Mountain, Durango, Mexico, wollastonite zones, 36
Safford Canyon, Nevada, 249
Sale, A. J., determination by, 645
Sales, R. H., on Butte chalcocite, 789; on native gold on chalcocite, 166; on primary origin of chalcocite, 790
Salina formation, 685
Saline domes, 536
Salines, literature on, 198, 303
Salt sand (natural gas), 521
Sand of Berea formation, source, 479
Sandstone-producing states, 469
Sandstones, geologic occurrence of, 469; uses of, 469
Sanford, Samuel, review of work by, 615

San Jose, Tamaulipas, Mexico, contact metamorphism, 35; analyses of fresh and altered limestones, 221
San Jose contact zones, 602
Sargent, R. H., method of measuring horizontal distances by aneroid, 732
Scale for mapping in field work, 268
Scapolite, 22
Schaller, W. T., analysis by, 317; review by, 298
Schneider, on precipitation of silver, 155
Schrader, F. C., *Alunite in Patagonia, Arizona, and Bovard, Nevada*, 752
Schnerman, E., on precipitation of metals, 408
Schuchert, Charles, discussion by, 588; on paleogeography of Ohio, 689
Scientific notes and news, 100, 204, 308, 403, 512, 617, 726, 817
Secondary enrichment, 407
Secondary enrichment in the Caledonia mine, Cœur d'Alene district, Idaho (Shannon), 565
Secondary silicate zones, 26; in contact-metamorphic ore deposits, 501; formation by infiltration, 49; formation by recrystallization, 46
Secondary sulphide enrichment, 456; definition, 781
Secondary sulphide enrichment and chalcocite formation at Butte, Montana (Rogers), 781
Secondary sulphides, mode of occurrence, 53
Sections—at Paria, Utah, 443; Berea sandstone quarries, 475; Cincinnati anticline to Allegheny Mountains, 523; correlation of strata from central Ohio to Allegheny Mountains, 539; lenticular sand containing gas, oil, and water, 534; of Butte, Montana, ores, 792; of norite-diorite from Plumas County, Cal., 782; Spindle Top oil field, Texas, 536; stratigraphic, measuring, 489
Sedimentary rocks invaded by intrusives, 20
Senator vein, Lawson, Colo., ore, polished section, 57
Sericite, 116
Sericitization, 111
Seven Devils district, Idaho, contact minerals, 40
Shannon, E. V., *Secondary enrichment in the Caledonia mine, Cœur d'Alene district, Idaho*, 565
Sharon conglomerate, 521
Sharwood, W. J., on analyses of mine waters, 657
Shaw, E. W., review by, 510
Sheffield sand (natural gas), 521
Shinarump at Paria, The gold of the (Lawson), 434
Shinarump clay, 437; properties, 444; analysis, 445
Shinarump group, 434
Shooting of wells, 686
Shoshonose, 253
Siderite, 417
Sierra Nevada vein, Cœur d'Alene district, Idaho, 566
Silica, in water, 663
Silicate zones, formation of, 606; by infiltration, 49; by recrystallization, 46
Silver, deposition of, 669; deposition from silver sulphate by sodium sulphide, 576; electrochemical action, 574; in Colorado ores, 51; in Fairbanks bullion, 450; literature on, 194, 301, 808; precipitation of, 416, 420
Silver, native, association with cobalt and nickel arsenides, 165; association with copper ores, 161
Silver and gold, Metallic minerals as precipitants of (Palmer and Bastin), 140
Silver, copper, and gold, cold acid sulphate solutions of, behavior with alkaline extracts of metallic sulphides (Grout), 407
Silver-lead deposits, Helena, Mont., 110
Silver-lead type of ore deposit, The tourmalinic (Knopf), 105
Silver ores, Colorado, mode of occurrence, 53; Lawson, Colo., polished section, 53, 55, 57
Silver salts, relative solubility, 152
Silver sulphate solutions, experiments with, 144
Simon, A. L., and Hatschek, E., on gels in relation to ore deposition, 550
Simonds, E. H., assays by, 446
Simpson, on Butte ores, 701
Singewald, J. T., Jr., *The microstructure of titaniferous magnetites*, 207; discussion of paper by, 610; review by, 298
Sinter deposits, paucity of precious metals in, 245
Silverbell, Ariz., ratios in unaltered and metamorphosed limestones, 503
Sisley, G. E., review of book by, 401

Sketching board, 382
Skey, W., on precipitation by sulphides, 141
Smaltite, 409, 417, 427; experiment in precipitating gold with, 159; experiment in precipitating silver with, 150
Smelting of titaniferous ores, 670
Smith, C. H., Jr., on rocks of Adirondack region, 223
Smith, F. C., discussion by, 383
Smith, George, on garnet formations of Chillagoe, Australia, 45
Smith, P. S., *The fineness of gold in the Fairbanks district, Alaska*, 449; discussion by, 393; on fineness of gold, 800
Smithsonite, 3, 4
Smyth, C. H., Jr., on rocks of northwestern Adirondacks, 45
Sodium, 239; in water, 663
Sokoloff, N. V., on origin of natural gas, 540
Solutions, cold acid sulphate, of copper, silver, and gold, behavior with alkaline extracts of metallic sulphides (Grout), 407
Solutions, alkaline, experiments with, 427; sulphate, experiments with, 410
Solutions and ores, Electrochemical activity between (Wells), 571
Solutions depositing chalcocite, chemical character, 646
Some notes on titaniferous magnetite (Brunton), 670
Some recent developments at Leadville; the oxidized zinc ores (Butler), 1
Sorby, H. C., mensuration method of, 124
South Amherst, Ohio, Berea sandstone industry at, 473
South Dakota natural gas, 526
Specific gravity, in determining grade of zinc ore, 14
Specimens, care of, in the field, 387
Specularite, 21
Speechley sand (natural gas), 521
Spencer, A. C., *Chalcocite enrichment*, 621
Spencer, L. J., on tourmaline ores, 118
Sphalerite, 10; experiment in precipitating gold with, 159; experiment in precipitating silver with, 150
Spindle Top oil field, Texas, 536
Spurr, J. E., on jarosite from the Mercur district, 320
Spurr, J. E., and Garrey, G. H., on copper deposits of Velardeña district, 23, 45; on pyrite as a product of vadose circulation, 458
Spurr, Garrey, and Fenner, on contact metamorphism, 232
Stadia survey, in field work, 384
Stannite, 417, 427
Stansfield, John, on rocks of Porcupine district, 486
Stanton, T. W., report on fossils by, 106
Starmount limestone, 326
Statistical literature, 306
Steamboat Springs, Nevada, hot waters, 245
Steiger, George, analysis by, 243
Stein sand (natural gas), 524
Stelzner, A. W., on Bolivian tin ores, 118
Stephanite, 51, 430, 431
Stevens, Blamey, discussion by, 397
Stevenson, J. J., on anticlinal theory, 542
Stewart, C. A., discussion by, 501; on garnetization at Silverbell, Ariz., 504
Stewart, C. A., and Welsh, T. W. B., on enrichment of copper veins, 625, 647, 648
Stibnite, 417, 427; experiment in precipitating gold with, 159; experiment in precipitating silver with, 150
Stockton district, Utah, plumbojarosite, 316
Stokes, H. N., analysis by, 333; on action of solutions on pyrite and marcasite, 408; on chalcocite deposition, 624; on experiments on pyrite and marcasite, 637; on pyrite and marcasite, 408, 459, 633, 640
Stokes test for chalcocite, 626
Stone, R. W., on rocks of Elkhorn, 106
Stose, G. W., discussion by, 389
Stratigraphic domes, 535
Stratigraphic sections, measuring, 489
Stratigraphy—of Shinarump formations, 438; Red beds, 771; southern area of Mid-Continent oil field, 776
Stream measurement, 344
Strike, determining, in field work, 278; line of, method of finding, 795
Structural dome, 535
Structural terraces, gas on, 532
Structure, determination of, in field work, 380

Structure of Mid-Continent oil fields, 778
Structure sections, preparations for figuring, 285
Stutzer, O., on contact metamorphic copper deposits, 23; on pegmatite-like deposition, 505; on tourmaline-bearing ore, 118
Sub-Olean sand (natural gas), 521
Subsample method of measuring rocks, 134
Sudbury pyrrhotite, analysis, 370
Sullivan, E. C., on formation of copper sulphides, 625; on interaction of minerals and water solutions, 418
Sulphate, cold acid, solutions of copper, silver, and gold, behavior with alkaline extracts of metallic sulphides (Grout), 407
Sulphate solutions, experiments with, 410
Sulphates and sulpharsenates as ore minerals in Utah, Occurrence of (Butler), 311
Sulphide enrichment, 407, 456; definition, 781
Sulphide enrichment and chalcocite formation at Butte, Montana (Rogers), 781
Sulphide enrichment, downward, metasomatism in (Bastin), 51
Sulphide ore body, A magmatic, at Elkhorn, Montana (Knopf), 323
Sulphide precipitation, 415
Sulphides, alkaline solutions of, 424; secondary, deposition of, 409
Sulphur, in water, 663
Sulphur Bank, Cal., hot waters, 245
Surface geology, methods for recording observations in, 90
Syenite, 556
Symbols for indicating data on maps, 179
Synthesis of pyrite, The vadose (Whitman), 455
Synthesis of pyrite, apparatus for, 462

Tables—Activity of alkaline solutions on sulphide minerals, 427; analyses of waters, 660; apparent dip of structure planes, 492; classification of sedimentary carbonaceous rocks, 562; deviations of intercepts of granite, 133; evidence on origin of secondary silicate zones, 28–44; frequency distributions of measurements of Maine granite, 132; intercepts of Maine granite, 133; mineralogical composition of oxidized zinc ores from Leadville, Colo., 16; order of activity of minerals in reducing acid ferric sulphate, compared with their activity on solutions of gold, silver, and copper, oxidized zinc ore, Leadville, Colo., 13, 14; percentages of minerals in subsamples, 133; quantitative mineralogical classification of holocrystalline igneous rocks, 556; quantitative mineralogical classification of sedimentary rocks, 562; rock groups, 553; rock series, 554; wells in Oberlin gas and oil field, 684, 688
Tacoma mine, Lucin district, Box-elder Co., Utah, plumbojarosite, 316
Temiskaming series, 485
Tennantite, 417; experiment in precipitating gold with, 159; experiment in precipitating silver with, 150
Terrace structure, gas and oil fields, 532
Tetrahedrite, 417, 427, 568
Texas natural gas fields, 525
Textural classification of the igneous rocks, 561
Theory of errors applied to the hand compass, 695
Thirty-foot gas sand, 521
Three-R mines, Patagonia, Ariz., 752
Tierra Caliente, Mexico, 578
Time for transfer of heat from magma to limestone, 230
Time required for determination of components of rocks, 138
Time traverse, 394
Tin, literature on, 196, 815
Tiona sand (natural gas), 521
Titaniferous iron deposits, exploitation of, 670
Titaniferous magnetite, Some notes on (Brunton), 670
Titaniferous magnetites, microstructure of (Singewald), 207
Titanium, 678; in magnetites, 611; mode of occurrence in magnetites, 207
Tolman, C. F., Jr., on secondary sulphide enrichment, 459, 633, 781
Tomboy lode, mineralogy of, 543
Tomboy mill, Telluride, Colorado, Artificial vein-formation in the (Kemp), 543
Tonalites, 552
Topographic sketching, 749
Tourmaline, 22, 109, 483

Tourmalinic silver-lead type of ore-deposit (Knopf), 105
Tourmalinization, 112
Tovote, W. L., discussion by, 720
Tower, G. W., and Smith, G. O., on minerals of Tintic district, 319
Trachyte, 251
Tracy sand (natural gas), 524
Travel, methods of, in field work, 379
Travers, M. W., on origin of natural gas, 540
Traverse methods, 388
Travertine, 241, 243
Tremolite, 22
Trenching of Shinarump clays, 442
Trenton limestone, 522
Tres Hermanas, garnetization, 39
Triangle method of control in surveying, 741
Triangulation, 731
Triassic brownstone belt, 469
Triassic of Plateau Province, 435
Turner, H. W., on fissures in Plumas Co., Cal., 786
Tuscarora mine, North Carolina, titaniferous ore, 211

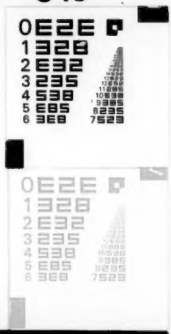
Udden, J. A., on oil fields of Texas, 778
Udden, J. A., and Phillips, D. M., review of work by, 189
Uglow, W. L., *A review of the existing hypotheses on the origin of the secondary silicate zones at the contacts of intrusives with limestones*, 19, 215; discussion by, 797; discussion of paper by, 597; on secondary silicates, 501
Umpleby, J. B., and Knopf, A., *Recent literature on economic geology*, 193
Unconformity, Bedford-Berea, 478
Underground hydrogeology, 399
Underground water resources of Virginia, 615
Underground work, methods of record for, 93
Up-to-Date mine, Caribou, Colo., ores of, 163
Upward secondary sulphide enrichment and chalcocite formation at Butte, Montana (Rogers), 781
Utah mine, Fish Springs district, Utah, plumbojarosite, 316
Utahite, 320

Vadose synthesis of pyrite (Whitman), 455
Valley Forge mine, Montana, 111, 114
Valley View claim, Bovard district, Nevada, 757; alunite at, 760
Van Hise, C. R., on enrichment, 621; on precipitation of argentite, 419; on secondary enrichment, 408, 781
Vein-formation, Artificial, in the Tomboy mill, Telluride, Colorado (Kemp), 543
Velardeña district, Mexico, garnetization, 38
Vermilion Cliff sandstone, 435, 443
Vertical measurements by aneroid and barygraph, 698
Vertical position, determination of, 748
Vesuvianite, 22, 609
Visual determination of grade of zinc ore, 12
Vogt, J. H. L., on action of ferric sulphate on chalcocite, 634; on genesis of ore deposits, 408; on veins, 117
Volume relations in chalcocite deposition, 642
Volumes, relative, of the components of rocks, The determination of, by mensuration methods (Lincoln and Rietz), 120

Wagon Wheel Gap, Colorado, The hot springs and the mineral deposits of (Emmons and Larsen), 235
Wagon Wheel Gap, Colo., hot springs, analyses of waters, 239; location, 235
Waihi deposits, New Zealand, 722
Walcott, C. D., on measuring sections of inclined strata, 489; on the Shinarump group, 435
Walking, in surveying work, 693
Warren sand (natural gas), 521
Washington, H. S., on time required for rock analysis, 138
Water, composition of, 662; depth in Colorado mines, 52; from mines, composition, 644; rôle in contact metamorphism, 232; uses in arid regions, 339
Water-power classification of lands, 350
Water-power site, defined, 351
Water resources, literature on, 198, 304
Water Resources Branch of the U. S. Geological Survey, 345
Water supply, from underground sources, 340; in arid regions, 337
Water table relations during chalcocite deposition, 649

Waters from regions of remote volcanic activity, average analysis of, 657
Waters of hot springs in regions of remote volcanic activity, 664
Waters of mines and of hot springs, A comparison of (Emmons and Harrington), 653
Weed, W. H., on Boulder hot springs, 245, 667; on Butte chalcocite, 789; on Elkhorn mining district, 323; on enrichment of gold and silver veins, 457; on hot springs, 657; on ore deposits near igneous contacts, 21, 45; on replacement in silver ore, 58; on rocks of Butte, Mont., 107; on silver in copper veins, 162; on secondary enrichment, 408, 621, 781; on upward secondary sulphide enrichment, 788; on vadose water of Butte district, Montana, 151
Weed, W. H., and Barrell, J., on Elkhorn mining district, Montana, 45, 222
Wegemann, C. H., on base measurement, 734
Wegemann, C. H., and Ransome, F. L., on the three-point problem, 185
Wells, Gas and oil, near Oberlin, Ohio (Hubbard), 681
Wells, R. C., *Electrochemical activity between solutions and ores*, 571; on electric potentials between conducting minerals and solutions, 634; on fractional precipitation of sulphides, 408, 430; on secondary sulphide deposition, 647
Welsh, T. W. B., and Stewart, C. A., on secondary enrichment of copper veins, 625, 647, 648
West iron mine, Palisade, Nev., 247
West Virginia gas fields, 522
Wheeler oil pool, Oklahoma, 777
White, J. C., on anticlinal theory of oil and gas accumulation, 529, 542
Whitehorse member, 772
White Knob, Idaho, analyses of fresh and altered limestones from, 220; contact metamorphism, 30, 31; ratios in unaltered and metamorphosed limestones, 503
Whitman, A. R., *The vadose synthesis of pyrite*, 455
Wichita Mountains, uplift of, 770
Wickes mining district, Montana, 111
Wilkinson, C., on precipitation of precious metals by sulphides, 141
Williams, I. A., mensuration method of, 124
Willis, Bailey, on field traversing, 375
Wilson, on origin of natural gas, 540
Wilson, H. M., on topographic surveying, 749
Winchell, A. N., on oxidation of pyrite, 408
Winchell, H. V., on Butte chalcocite, 789; on chalcocite deposition, 624; on synthesis of chalcocite, 408
Winchell, H. V., and Winchell, A. N., on tourmalinic copper-silver ore, 118
Wolftonite, 8
Wollastonite, 22, 28
Woodward, H. B., review of work by, 510
Woodward formation, 771, 772
Wyoming natural gas, 526

Yung, M. B., and McCaffery, R. S., on ore deposits of the San Pedro district, New Mexico, 45

Zaloziecki, R., on origin of natural gas, 540
Zinc, literature on, 195, 302, 813
Zinc carbonates, Leadville, Colo., discovery, 2; position and character, 4
Zinc ores, oxidized, Leadville, Colo., 1; grade of ore, 12
Zirkel, F., on origin of ore minerals, 23

C15